ARROYO SECO

SCIENTIFIC AMERICAN SUPPLEMENT

Copyright, 1919, by Scientific American Publishing Co.

VOLUME LXXXVIII] NUMBER 2282

★ NEW YORK, SEPTEMBER 27, 1919 ★

Published weekly. Entered as second class matter December 15, 1887, at the Post Office at New York, N. Y., under Act of March 3, 1879

[10 CENTS A COPY $5.00 A YEAR

© Underwood & Underwood

Scraping and baling shed in a cork yard near Alimoriama, Spain

PREPARING CORK FOR SHIPMENT (See p. 200)

Benzinoform in High-Tension Oil-Break Switches*

Some Recently Revealed German Experiences With Substitute Materials

By M. Vogelsang

WHILE it is quite true that danger from explosion in high tension oil break switches can be almost entirely prevented by the correct construction of the apparatus, the inflammability of the oil is undeniably a grave fault in such switches. The accumulation of such large quantities of inflmammable materials for processes which are necessarily carried out under conditions which involve the production of fire is undesirable and quite aside from the possibility of an explosion in the oil-break-switch itself, there is always the possibility that an accidental fire may occur during the course of the work being done, in which case there is a danger that the oil of the switch will offer fresh fuel to the flames.

On this account it seems to be proper to describe the experiments which have been conducted for a considerable length of time by the Voight and Haeffner Company, with the object of replacing the oil in these switches by another and non-inflammable fluid. This fluid is carbon tetra-chloride, known in commerce as benzinoform. These experiments have met with at least a temporary degree of success. I must state in the beginning that this does not mean that we can empty the oil from our switches at once and fill them with benzinoform—for the latter unfortunately also has some unsatisfactory qualities—at the same time I consider the results obtained important enough to make public, above all, in order that technical experts and professional chemists may be led to direct their attention to this entire question.[1]

It seems probable that the possibility of making such a use of benzinoform was first announced in the D.R.P. No. 218,399 taken out by E. Peyrusson of Paris in December 1908. In the meantime this patent has expired. In this patent benzinoform was recommended for the filling of switches on account of its non-inflammability and its high degree of insulating power; the properties in question of the benzinoform were described in the patent and a method was indicated by which the evaporation of this fluid could be prevented, namely, by covering it with a layer of either water or glycerine or still better by a mixture of equal parts of the two.

So far as I know the matter is at present neglected, or, at any rate, if experiments along this line have been made elsewhere nothing in regard to them has been published.[2] There is no occasion for surprise in this when we recall that the fear of oil-break-switch explosions did not begin to spread in Germany until about 1911.

In April of that year the first experiments with benzinoform were begun by the Voight and Haeffner Co., but without knowledge of the patent mentioned above. However, the matter was abandoned at that time and not until three years later, in April 1914, was it taken up once more. After the beginning of the war the experiments were continued with a special zeal, since at that time the oil was extraordinarily scarce, and we had it in mind to use the benzinoform as a substitute. As the war continued, however, the tables were turned since oil began to be delivered again, while the benzinoform was hard to obtain because the raw materials were curtailed, as was also the glycerine.

Benzinoform or carbon tetra-chloride (CCl_4) is a fluid which has a specific gravity of 1.63, which boils at 76.5° C. and which evaporates very rapidly in the open air, like benzine; it is a non-conductor of electricity, and is non-combustible.

The high specific weight of benzinoform in comparison with oil (1.63 to 0.91) must be taken into consideration in practice. The handling of full vessels, the charging the covers with switches filled with benzinoform is considerably less easy than with oil break switches.

With respect to the readiness of evaporation of the benzinoform we experimented to see whether it was possible to get along without covering the upper surface of the fluid with the layer of glycerine referred to above. In the first place a closed oil break switch of the ordinary type with terminals was filled with benzinoform which was allowed to stand without any special packing; a daily decrease in the height of the liquid amounting to 1 millimeter was observed in this case. The switch was then made as tight as possible with felt or some similar material, but in this case also there was a regular daily decrease of half a millimeter in the height of the liquid. Evidently, therefore, the switch must be made tight like a boiler with special care in order to avoid a loss of fluid. This, however, is not very easy to do on account of the necessity of the insertion of valves. Other methods, such for example as the tightening of the cover drainage through a channel, are subject to serious objections since such a tight joint made by means of a liquid is liable to be forced away through the switch processes, which involve an enormous increase of pressure.

The attempt was next made to lessen the amount of evaporation of the fluid by putting a float upon the top of it. The effect of this was extremely slight. Evaporation continued to take place even through the crevice between the float and the wall of the vessel and was almost as great in amount as without the float, presumably because the liquid rises somewhat along the wall of the vessel, and the edge of the float, through capillary attraction.

It is naturally of importance, with respect to the practical utilization in switches of benzinoform to know how the latter behave with respect to various materials. On this account we conducted experiments with the various metals and other materials concerned, by exposing test pieces to the action of benzinoform, sometimes for more than a year at a time. The general result first noted was that the effect of the benzinoform is much more powerful when it is kept continually heated to a temperature of 45°C. than at a normal temperature. While copper, for example, was scarcely attacked at all at ordinary temperatures, when it is long exposed to the warm benzinoform it displayed a white, slimy surface layer which was found to have eaten deeply into the metal. The metals aluminum, silver, lead, and especially tin, behaved especially well in this respect, so that any metal part concerned can be readily protected by being plated with tin.

Among other materials, rubber, hard rubber, "Pertina" and "Mikanite" proved absolutely non-usable. Fiber and mica remained entirely unaltered; it was also noted that the litharge cement which is such an important material in the construction of switches retained its firmness, though its external surface turned black.

We next undertook the testing of benzinoform as an insulating material. Our experiments showed that in the case of benzinoform there is a marked difference between the average values of an instantaneous charge and those of a permanent charge. For this reason two curves were plotted, both of which are represented in Fig. 1 [omitted]. The first curve shows the perforation distance in an instantaneous charge, i. e. one lasting about the space of two seconds. In the other curve those tension values are compared which correspond to those distances in which a perforation did not occur within the space of twenty minutes. The perforation tests were carried out in a suitable trough, point to point. It is to be noted that these comparative tests shown in the curves were carried out with benzinoform which had already served for short circuit tests and which was, therefore, already colored brown. It was manifest here, just as in the case of oil, that the clouding of the liquid in consequence of its use in the switch, does not seriously interfere with the use of the material. The test values as to the perforation are not entirely exhaustive. On account of the war it was not possible to institute more exact and more extended experiments. The test values appear to be sufficient, however, within the compass of this report since they indicate that in relation to the distance of separation of the electrodes the insulation, the benzinoform is always utilizable for medium high tension and probably also for extreme high tension.

Attention may be called to the fact that the characteristic property of benzinoform, that of exhibiting a considerably higher insulation value in case of a supercharge of short duration than in case of a continuous charge is advantageous with regard to the materials of the switches; for the dangerous charge is not the ordinary tension but some chance super tension, and it is characteristic of such super tension always to be of short duration. It should be mentioned that a tolerably vigorous movement is produced by the electrification in the fluid. This movement is perceptible in the oil also but is comparatively small, while in the benzinoform it is quite marked and pretty vigorous. The difference between the perforation distances in the continuous charge and the instantaneous charge may be connected with this phenomenon.

In September 1914, a switch intended for continuous use in the operation of a testing room, was filled with benzinoform and regularly put into commission for permanent employment. The benzinoform was kept constantly covered in this case, as in all later experiments with switches, with a layer of glycerine. This testing-room switch is provided with a glass window in front so that the operations of the switch can be supervised. After a short time the switch was again examined and an observation was made which was of great practical importance, thought it was not very encouraging. *After a short lapse of time, something like a month, all of the copper parts were found to be covered with a slimy layer of verdigris.* It was found, however, that this phenomenon had nothing to do with the benzinoform itself but that in the letting down of the oil vessel, the parts of the switch were drawn through the layer of glycerine on top and the effect of this was the formation of the aforesaid disagreeable verdigris. It is, therefore, unfortunately impossible in making use of such a benzinoform switch with the glycerine covering to employ the usual box lowering arrangement in order to inspect the contacts.

This first experimental switch placed in the testing room was employed for very different tensions, up to 10,000 V. at times though usually it was about 5,000 V. After being in operation for six weeks, incidentally with a charge of 5,000 V. towards the earth the switch turned over, and that from a tension conducting part toward the glycerine surface. The switch was put out of commission and replaced by another with insulators dipping more deeply into the fluid. Until the end of 1914 daily short circuits were made upon this switch. Nothing unusual was observed until at the end of March 1915, an earth circuit again occurred. It turned out that the height of the fluid had sunk a distance of about 26 millimeters in consequence of a slight lack of tightness of the box and it may be pointed out in this connection that unfortunately *such a lack of tightness is almost impossible to detect from the outside on account of the ease of evaporation of the benzinoform;* this is in contrast to the action of oil, since the leaking out of even a few drops of oil always reveals itself by the formation of a large spot.

The testing-room switch, which as a matter of fact was an old out of date form, was of interest to some extent, since it was in very constant operation and with the most various tensions. However, it is not in immediate contact with the voltage of the system.

In consequence of this the quantity of energy in the switch processes is not very great even in short circuits (the transformer lying between has about 50 kva). On this account it seems to be desirable to extend the experiment to such switches as are in immediate contact with a high tension system. The manufacturing plant was supplied from an electric establishment in Frankfurt with 3,000 V. one phase alternating current. Although the plant is operated in part with a direct current, the machine works consist essentially of a transformer group. The switches ("type R, series III") all have electro-magnetic control. In the spring of 1915 four of the regular switches in the transformer plant were filled with benzinoform and put into commission. Of these four the switch of the 220 small kw-transformer was most used in the regular business and it was also the only one in which bad conditions were observed. After a few days the switch stuck; this circumstance was traced to the fact that it was no longer lubricated in the act of switching as was formerly the case when oil was used. After the cut-out spring was altered this condition appeared again. Thereupon the cut-out coil was strengthened whereby the aforesaid fault was finally eliminated. The night after the switch was put into operation again, after being reconstructed, passages of current manifested themselves in the cut-out switch, and these were accompanied by other phenomena of a violent and unpleasant nature. The whole room became filled with fumes. This occurrence was traced to the fact that the filled switch had been taken away and that the

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from the *Elektrotechnische Zeitschrift* (Berlin).

[1] See also *Elektrotech. Zeitsch.* 1916, p. 124.

[2] We called attention at the time to the use of carbon tetrachloride for the purpose of high tension insurance; see *Elektrotech. Zeitsch.* 1915, p. 740, and also 1916, p. 124.

glycerine, because of the shaking up, had covered the insulators with a conducting layer. Thereupon the switch was thoroughly cleaned and the next day was found to operate smoothly. The same fault manifested itself again later. This time it could only be traced to the movement of the glycerine layer occasioned by the frequently repeated switching, since the other switches operating under similar conditions in other respects did not exhibit this fault.

Naturally it seemed very desirable to conduct experiments in order to ascertain how a switch filled with benzinoform would behave in a short circuit of a serious nature. The managers of the Frankfurt Electric Works very accommodatingly allowed us to undertake short circuit experiments with a benzinoform switch at their establishment. These tests were begun on the 24th of August 1915, with an 1100 kw machine with a 3000 V. one phase current. The machine was operated by a piston steam engine.

So far as the switch was concerned it was attempted to make the conditions of the test as unfavorable as possible for the work done by the machines and the tension are not vrey great in a short circuit experiment with high tension. The switch experimented with was the Voight and Haeffner Company "type RHDH, series II." The boiler has a content of 75 liters, the distance from the place of interruption to the glycerine superficial layer was 195 millimeters, and the depth of the glycerine layer was 18 millimeters. The switch which was standard and three-poled was arranged for the purpose of the experiment in the following manner: Between one of the side poles and the middle pole a leaden partition was erected so that the switch was divided into two unequal portions having the ratio of 1 to 2. The partition unfortunately had underneath a slit to allow of the movement of the switch traverse so that both portions of the vessel were in free communication with each other as a result of which an unpleasant effect was produced in the second experiment. Only the one separated phase was employed as a switch, i. e. a switch knife with two interruption points. On the switch itself there was the maximum relay for the purpose of a direct cut-out, which was designed for a cut-out current having a strength of 200 A and which operated without being reduced. A circuit was then installed which was formed only by the experimental switch and a one-poled knife switch connected in series so that by the interpolation of the one-poled knife switch a short circuit upon the previously inserted experimental switch could be made in a very simple manner. For the sake of certainty a standard two-poled oil-break-switch with a time relay was also inserted in the circuit to provide for the possible chance of a test switch failing to operate. However, as it turned out the oil switch did not need to be used.

In the first experiment was carried on at 3,000 V. and then the above-mentioned knife switch was closed. The test switch immediately cut out irreproachably without anything observable from the outside. Since unfortunately the box could not be lowered on account of the glycerine layer, it could not be certainly determined whether the contacts caught fire.

In a second experiment the tension was brought to 3,250 V. The test switch also switched out in the short circuit but not until after a perceptible though brief lapse of time. Moreover, there was manifested a considerable excess pressure in the box, since the benzinoform was driven too high out of the smaller part, the real switching room, through the above-mentioned slit into the other and larger part of the vessel, and on this side it overflowed the side of the box somewhat (about one-half a liter).

The box was now lowered. The benzinoform was found to be colored a dark brown but the box was in no way altered. The contacts exhibited charred places and here and there a black deposit which, however, was easily brushed away. It was also observed that besides the interrupting pieces the corners of the knife were much burnt. The voltaic arc was, therefore (a fact which was already familiar), driven out sidewise by the electro-dynamic effect towards the contacts; this was also to be observed in the box, for the corresponding opposite lying points of the box were blackened and in one place a small burn was visible At the fixed contact pieces the fire had climbed up on the outer side to the top.

The result in the second experiment and the subsequent state of the apparatus indicate that to begin with the one-sided pressure charge in the vessel produced by the provisory experimental arrangement has an obviously unfavorable action. Perhaps this is why the formation of arcs in the liquid was comparatively great. The fact that the switch was somewhat tardy in the cut-out may possibly be ascribed to a brief burning process, the probable reason for which was that the contacts had already been attacked by the first short circuit. It may be said in general that *the lack of any lubricating effect when benzinoform is employed instead of oil, is very characteristic*, as was shown, indeed, by the previously mentioned experiments. The springs by which the automatic cut-out is effected must always be more stoutly constructed than in the case of oil-break switches in order to prevent the switch from sticking when a short circuit occurs.

As has already been mentioned the experiments with benzinoform as a substitute for oil in switches were not so favorable as to justify a change without reservation. The great amount of evaporation of the benzinoform and the necessity of obviating this by a surface layer of glycerine, i. e. with a fluid that is a conductor, involves not inconsiderable practical difficulties in the operation of the apparatus, as likewise in the practical handling, filling, emptying, cleansing, etc. Moreover, the possibility of inspecting the inside by the lowering of the vessel is excluded. On this account naturally the aforesaid construction for the utilization of the benzinoform is of prime importance; the kind formerly used makes it impossible readily to inspect the inner parts. We refer to the closed switches in which the transmission insulators are attached to the bottom of the switch. These apparatuses would be comparatively easy to construct in such a manner that the part moved by the penetrating glycerine layer will be confined essentially to a round rod; by this means the disadvantage attendant upon the glycerine layer would be confined within narrow limits. By employing this method, therefore, a practically usable benzinoform switch can even now be constructed when this is greatly desirable.

The whole question, moreover, may be considered from another point of view, i. e. since benzinoform forms an intimate mixture with oil, we obtain through such a mixture a fluid which does not perceptibly evaporate in the open air and which, while not non-combustible, is, at any rate, much more difficultly combustible than oil. After a few preliminary experiments a mixture of 25 parts by volume of benzinoform with 75 parts by volume of oil was found to be suitable for such use. That the benzinoform loses comparatively little through evaporation in such a mixture is proved by the fact that the mixture suffered a decrease of only 5 per cent after being heated for three hours at 100°C. The fact that the two fluids are very intimately mixed is the more apparent after this experiment when we recall that the boiling point of benzinoform is about 76.5°C. When we picture to ourselves the switching process we are obliged to believe that such a mixture behaves comparatively well, since the first effect of the switching arc is always to cause a distilling out of the benzinoform. It is possible, therefore, that we may obtain in this manner an improvement of the switch oil by the addition to it of benzinoform. Extended practical experiments along this line have not been made as yet. It must be remembered, naturally, in case a fire breaks out in a switching plant, that the contents of the vessel containing 75 parts by volume of oil is far from being non-combustible.

It may be mentioned here that a short time before the war various speciments of "non-combustible switch oil" were offered for sale, and it seems probable that these consisted of a mixture of benzinoform and oil.

In these experiments we confined ourselves to the use of pure benzinoform covered with a layer of glycerine. It was this entirely non-combustible fluid which was primarily of the greatest interest to us, since operators were accustomed to reckon with the combustibility of fluid insulating mediums for switches as an inevitable fact. But it now appears that a fluid capable of offering excellent insulation is non-combustible and although it has another unpleasant quality yet its existence proves that the power of insulation and the property of combustibility are not inevitably linked together. This justifies the hope, perhaps, if the science of chemistry attacks this problem energetically—and I am convinced that chemists are not aware of this problem—that it may prove possible to discover a fluid which will not only possess the admirable properties of oil as regards use in electric switches, but also the property of non-combustibility.

Evolution of Gas When Fused Sodium Hydroxide Is Dissolved in Water

It has frequently been observed that when fused sodium hydroxide is dissolved in water a gas of piercing odor is evolved. The author has shown that this effect is produced by the action of a very small quantity of oxygen which is set free by the decomposition of a chemical compound and escapes mixed with air.—*W. H. Schramm* in *Chemiker Zeitung.*

Boring in Trinidad Asphalt Lake

Recent borings made in the famous asphalt lake on the Island of Trinidad have, according to the *Contract Journal*, reached a new low level record of 150 ft. The previous record, made in 1893, was 135 ft. On both occasions the asphalt was found to be of uniform character throughout. These latest attempts to find the bottom of the great mass of asphalt were conducted by George A. Macready, geologist, at the instance of Dr. Clifford Richardson, who has studied this asphalt wonder for many years. Great difficulties attend any attempt to sound the lake, as it is in constant, though almost imperceptible, motion. The pressure of the mass of asphalt at any great depth against the drilling apparatus causes it to bend and the deflection from the perpendicular is so great that further boring is prohibited. In the borings which have just been made a core of asphalt was taken by driving a small pipe into the pitch and then withdrawing it with its contained core of pitch. Following this, a pipe of 2 in. diameter was driven to the lowest depth to which the core was taken and the material forced into it by driving was removed by means of a water jet and bit. Another core was taken below the 2 in. pipe in the untouched pipe. The deepest of these borings was taken at the center of the pitch lake and the asphalt was found to be of uniform character throughout. After completion, this hole was observed to have shifted at the surface 25 ft. in six weeks; a survey showed the movement to exist as deep as 100 ft., and there was a suggestion that the direction was reversed at a depth of between 25 ft. and 50 ft. The other borings, not at the center of the lake, shifted to a lesser extent. The movement of the asphalt seems to be similar in many respects to the ascending and descending currents in a kettle of boiling water.

The problem presented is difficult of solution, as it seems to be impossible to find any material which will withstand the bending strain imposed upon it by the pressure of the mass of semi-solid asphalt.—*Engineer* (London).

Diffraction of Electric Waves by the Earth

The earth is supposed to be a homogeneous imperfectly conducting sphere of radius a surrounded by infinite homogeneous dielectric. The transmitter is a Hertzian oscillator at distance b ($> a$) from the center of the sphere with its axis, taken as the axis of harmonics, radial to the sphere. The oscillator emits simple harmonic waves of period $2\pi/\omega$, and the electric and magnetic forces are the real parts of the vectors $E e^{i\omega t}$, $H e^{i\omega t}$, E and H being related by the equation $\beta E = \text{curl } H, \gamma H = -\text{curl } E$, where β and γ are constants of the transmitting medium. The problem is then the purely mathematical one of the approximate summation of a complicated oscillatory series. Poincaré [Abs. 1322 (1910)] and Nicholson [Abs. 430, etc. (1910)] replaced the series by an integral which was then approximately evaluated by the calculus of residues. These approximations, however, became invalid near the antipodes of the transmitter, and the author considers their analysis defective in some points of detail. Macdonald [Abs. 1313 (1914)] approximates to the terms of the series and then replaces the modified series by an integral under conditions not strictly justifiable mathematically, and, moreover, uses an approximation not valid to the extent assumed, which is the principal source of the discrepancy between his results and those of Poincaré and Nicholson. March [Abs. 569 (1912)] and Rybczynski [Abs. 1489 (1913)], in dealing with an oscillation on the positive half of the axis of harmonics, express a Hertzian function by an integral of $P_\nu (\cos \theta)$, whereas in dealing with harmonics of non-integral degree, the appropriate function is $P_\nu (-\cos\theta)$. This, as Love has pointed out in a directly arithmetical treatment of the problem [Abs. 1109 (1915)], vitiates the whole of their analysis, the expression assumed for the magnetic force having a line of singularities along the negative half of the axis of harmonics.

The present author starts with a Hertzian function identical with that of Love in the case of an oscillator surrounded by infinite homogeneous dielectric, and identical also, except for a formal factor, with that of March. Avoiding the error pointed out by Love, the series for the magnetic force is derived from the Hertzian function, and is then transformed by the calculus of residues into a rapidly convergent series well adapted to numerical computation. Poincaré's analysis leads only to an approximation to the dominant terms of the latter series, but the more powerful contour integrals of the present paper give the complete series. The use of the Hertzian function and Bessel function of the types employed by March, makes the analysis remarkably concise.—*Sci. Abstr.*

Stress Lines in Steel After Permanent Deformation*

Study of Hardening at Various Distances from the Point Altered by Hammering, Punching or Shearing

By Andrew McCance, D.Sc., A.R.S.M.

It is usual to distinguish two modes by which materials of construction, and especially metals, may have their shape altered and be deformed under the influence of applied stresses—elastic deformation, which exists only during the application of the stress, and plastic deformation, which persists after the stress has been removed.

Elastic deformation takes place when the metal is stressed below its elastic limit, and it does not claim consideration in this note. Plastic deformation takes place when the elastic limit has been exceeded, and it modifies permanently all the physical properties of the metal in varying degrees, and these can only be restored to their original values by annealing. When

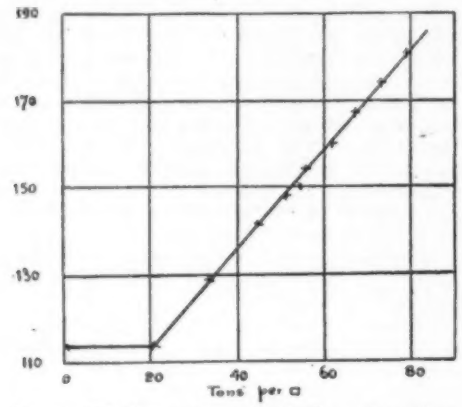


Fig. 1—Relation between hardness and previous stress in a mild steel

the shape of a piece of metal has been altered in the cold state by hammering, punching, drifting, or shearing, the metal is plastically deformed, and generally the effects which such treatment produces are referred to as the effects of "cold work."

Principal among such effects is the hardening which cold work produces, and it is this subject which I wish to draw attention to in more detail, and to show how this property can be used to give an insight into the stress distribution in certain cases where the ordinary elasticity theory does not apply.

Hardness is one of those physical properties about which nearly everyone thinks he has clear ideas until he tries to put his conceptions into quantitative form, when the difficulties which were not previously apparent become very real. Roughly speaking, it is the property by means of which a material resists penetration, and to express it quantitatively the pressure can be measured which will just produce a permanent impression on the material under test when another body of fixed shape is pressed against it. This was the original method of Hertz and Auerbach, but it is of no practical use because of the difficulty of determining when a permanent impression has been made. In the Brinell modification of this method a hardened steel ball is pressed under constant pressure into the test piece, and the pressure divided by the area of the impression gives the hardness number. This Brinell hard-

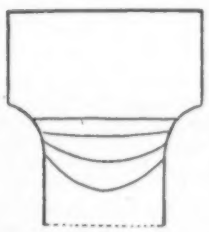


Fig. 2

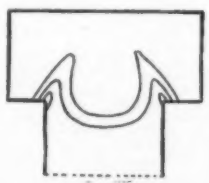


Fig. 3

Figures of stress lines showing effect of shoulders

ness number is purely arbitrary and relative, but the method is very conveniently carried out, and it is of great practical use.

Recent work has shown that the volume of indentation is directly proportional to the energy expended in forming it, and also independent of the shape of the tool, so that this at once gives a rational hardness number independent of the method by which it is attained.

Another method of determining hardness is by means of the Shore scleroscope, which depends on the principle that a blow of constant energy will deform to an extent which will be less the harder the material is. A small pointed hammer is allowed to drop from a fixed height, and the height of rebound measured. This height will obviously be some function of the energy unabsorbed, and consequently of the hardness—the greater the hardness the greater the height of rebound, though not proportionally. This method is especially useful for determining the uniformity of treatment in hardened steel articles. For material of low hardness there is some difficulty in reading the height of rebound accurately, and in every case irregular results are obtained unless the surface of the test is fairly highly polished.

It has been shown that the height of rebound is proportional to the coefficient of restitution, which in many cases seems to depend on the hardness and increases with it. But there are in consequence peculiar anomalies with the Shore instrument, such, for instance, as the hardness of rubber being greater than that of mild steel. One great advantage which it possesses is that the area of the impression is small—in the neighborhood of 20 thousands in diameter—so that determinations can be made very close together, and in most of the experiments quoted in this paper the hardnesses were determined by the scleroscope.[1]

As mentioned above, steel which has been cold worked has its hardness increased, and if small cylinders are stressed by known amounts in a testing machine, and the increase in hardness measured, a curve can be drawn showing the relation between the hardness and the previous stress. Figure 1 is such a curve for a mild steel containing 0.18% carbon, and it will be seen that there is a straight-line relation between the increase in hardness and the stress after the elastic limit has been passed. This could be used to determine the elastic limit without an extensometer. This curve can be put to some use now, because if a piece of steel has been permanently deformed in any unknown manner, by taking the hardness at any point and referring back to the curve the stress to which the piece has been subjected can be found. In most cases, however, it is of interest only to know the distribution of the stresses without knowing their values, and so lines of equal hardness will give also the lines of equal stress.

One question of great importance regarding the theory of hardening by cold work may be mentioned here in passing. A small cube of steel was compressed with a pressure of 80 tons per square inch, and the Brinell and Shore hardness was taken along the direction of stress and at right angles to it, giving the following figures:

	Normal.	Along.	Across.
Brinell	114	197	219
Shore	15	23	24.5

Another test was submitted to a tension stress of 30 tons per square inch, and similar hardness determinations were taken:

	Normal.	Along.	Across.
Brinell	129	179	171
Shore	19	24	23

These differences, though small, are out with the errors of experiment, and they indicate that in cold-work hardening there is a connection between the direction of stress and the degree of hardening produced. This curious effect may be produced by variations in the elastic limit, but the whole question is so important that further work is being undertaken with purer samples to lessen the possible influence of heterogeneity.

THE EFFECT OF SHOULDERS.

The effect which a shoulder has will depend on the radius at the junction of the two dimensions, and this can be seen in tensile tests which have rounded shoulders, Fig. 2, or sharp corners, Fig. 3. In the first case the stress lines are either straight across or are gently sloped, while in the second case the most severe stress is located at the corners. In the latter the dotted line shows where the fracture ultimately took place when the test was pulled.

If a sharp corner occurs at any change of section under stress it will lead to a similar intense localization of high stress, and increase to a very great degree the chances of forming cracks through fatigue.

A result not readily expected is shown by both samples where the stress at the center of the test is less than that at either edge. This is a shoulder effect which can be explained in the following manner: Since with every longitudinal strain there is a corresponding lateral contraction—the ratio of the elastic strains being Poisson's ratio, which is constant—with permanent strains the ratio is not constant, but decreases as the strain gets greater. Theoretically the ratio for small strains should be 0.5 if there is no change in volume on straining, but it should decrease

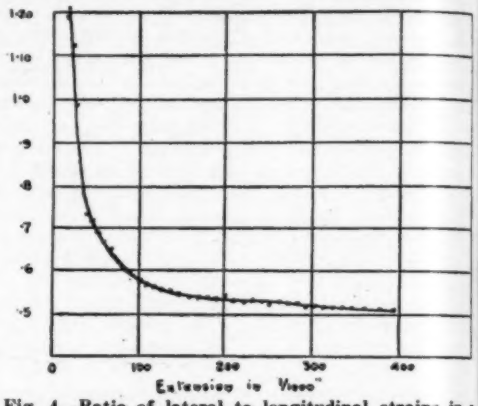


Fig. 4—Ratio of lateral to longitudinal strains in a 2-inch piece stressed by increasing amounts

for larger strains; actually there is a small increase in the volume on permanent distortion, so that the value is somewhat less than the theoretical of 0.5. If under any conditions the value is a when the longitudinal strain is x the lateral contraction will be ax. If now a lateral expansion is brought about so that the diameter is brought back to its original value, the corresponding longitudinal strain will be a^2x, and the total strain will now be $(1 - a^2)x$. Any constraint which prevents the lateral contraction will lessen the strain, and the effect of a shoulder will be to prevent the movement of material contiguous to it. In a test piece the outside surfaces are free to move, but at the center near the shoulder the movement will not be free, but will be constrained so that the total strain will be lessened, which is shown by the decrease in hardness. It is very surprising to find how far the effect of the shoulder extends into the test. In a 2-inch parallel test-piece (prepared to the dimensions of the Engineer-

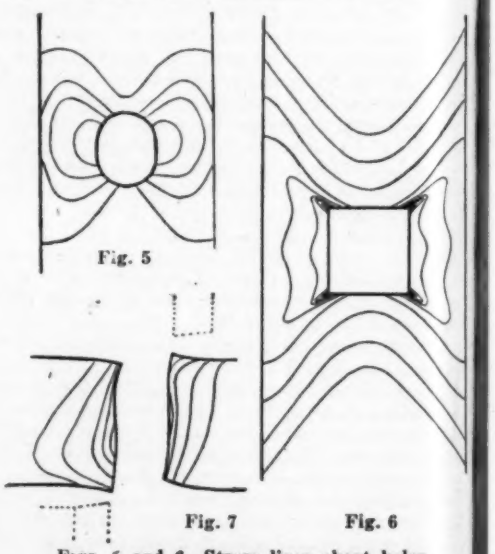


Fig. 5

Fig. 7

Fig. 6

Figs. 5 and 6—Stress lines about holes
Fig. 7—Stress lines about sheared edges

ing Standards Committee) which was stressed by increasing amounts, the ratio of the lateral to the longitudinal strains is shown in Fig. 4. Instead of 0.5 for small strains the value is 1.2—all the permanent set is taking place at the center of the test piece owing to the restraint of the shoulders. The value quickly gets less, but it is always above 0.5, although with a long wire from which the shoulder effect is absent it is below 0.5, and never gets above it. It may be mentioned that the test previous to the experiment was ground parallel over 2 inches to within 0.0005 of an inch, so

*From *Trans. Instit. Eng. & Shipbuilder, Scotland* (Glasgow).

[1] See Sci. Amer. Suppl., No. 2273, for July 26, 1919, p. 58, for accounts of scleroscopes.

that the effect is not due to any reduced section at the center of the parallel portion.

THE EFFECT OF HOLES.

The concentration of stress at the edges of a hole in a plate submitted to tension has been demonstrated both theoretically and by experiment, and the determination of the variations in hardness gives another method which is not without its advantages. The results for a circular hole, Fig. 5, confirm that the maximum deformation takes place at the inner edges at right angles to the direction of tension. From the hardness-stress curve the tension on this inner surface is approximately 30 tons per square inch, that at the corresponding outer edge being only about 20 tons—while the stress calculated on the stress/minimum area had a maximum value of 26 tons per square inch. As the breaking stress was only 32 tons, this section was very near its breaking point, and had there been any tendency towards brittleness in the material, or had a small crack started at the surface, failure would have resulted. Although the condition here presented cannot, of course, represent any condition of practical service the illustration may bring home in a graphic way the fact that with a row of holes, for instance, in a boiler plate under stress, the stress to be allowed for in design is not simply the value obtained by dividing the maximum stress by the minimum area.

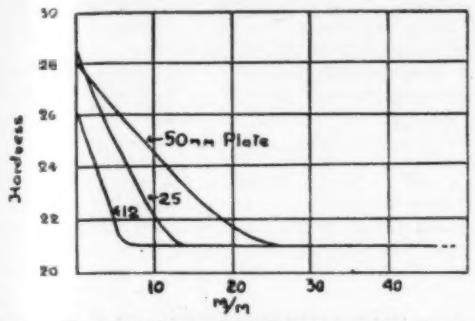


Fig. 8—Extent of hardening effect due to shearing in plates of different thickness

The case of a square hole is shown in Fig. 6, and the distribution is a combination of the effects of a square shoulder and a circular hole. In this case the maximum stress on the reduced area was 24.5 tons per square inch, but from the hardness the maximum stress at the corners reached 29 tons, which is again very near the breaking limit.

SHEARED EDGES.

When a steel plate is sheared the edge of the plate after shearing is in a highly cold-worked condition, and it is decidedly harder and more brittle than the normal material, and the distribution of hardness on the plate and scrap after the shearing cut is shown in Fig. 7. There is a considerable difference between the volumes of strained material in each half, the edge under the moveable top-blade having been more locally deformed than the corresponding edge under the fixed bottom-blade. Why this should be so it is difficult to imagine, but it is probably connected with the state of the cutting edge of each blade, the top blade in this case having been sharper than the bottom blade. This reason is supported by the extent of the local deformation under each blade.

It is of some importance to know how far this hardening effect extends, and by taking the hardness down the center line of plates of different thicknesses Fig. 8 has been drawn. It will be seen that the effect extends into the plate by an amount almost equal to half the thickness.

The increase in hardness at the extreme edge is very considerable, amounting to about 60 per cent, and this very hard layer, which has been deformed up to the rupture limit, cannot stand any further extension without the rupture extending inwards and forming cracks. If strips are cut about 3/16-inch wide parallel to the sheared edge, the first strip containing this hard layer will only bend a few degrees before it breaks; while the next strip will bend almost double, although not without the formation of a few cracks at the outer surface. At least ¼ and preferably ½ the thickness should be removed therefore from the sheared edge before the danger of cracking is removed. The severe distortion can be made visible by examining a section under the microscope.[2]

All plates which have to be bent cold should have this amount of metal removed first if they have been sheared to size before their shape is altered in any way. This cannot be too strongly emphasized, because numerous failures in boiler plates could have been avoided if the sheared edge had been removed before the plates were bent. In cases where it is not imperative that this layer be removed the same result can be obtained by annealing the plate after shearing, and it has always seemed to the author an inversion of the proper sequence in operations that mild-steel plates are annealed first and then shorn, when the correct course to adopt should be to shear first and then anneal the plate in order to remove the effects of shearing from the edges.

Exactly the same effects will exist at the edges of a hole which has been punched in a plate, but the author has not thought it necessary to include any examples. The dangers arising from this layer of hardened material in a punched hole will be increased by the concentration of stress round the edges of the hole shown to exist in a previous section, so that in work where this class of workmanship is used it is essential that much more liberal allowances in the factor of safety be made than in those cases where all the holes have been drilled.

IMPACT TESTS.

Within recent years impact tests have been extensively used for the detection of brittleness in steels and other materials, and they have undoubtedly proved of great value. Such tests measure the energy required to rupture a specimen of known dimensions which contains a notch of definite shape, the energy being generally measured by letting a swinging weight fall from a standard height and noting the height which it attains after breaking the test piece—the difference giving the energy absorbed in rupture. Such tests should really be called notched-bar tests, however; because the differences between a tough and a brittle material are not brought about by the impact or suddenly applied stress, but by the presence of the notch. The same distinctive differences can be obtained if the stresses are applied slowly to specimens similarly notched. Much confusion of thought would be avoided if this were recognized.

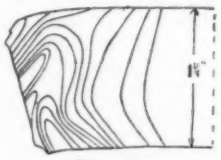


Fig. 11

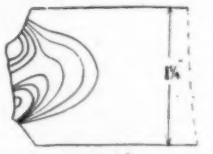


Fig. 12

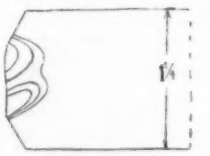


Fig. 13

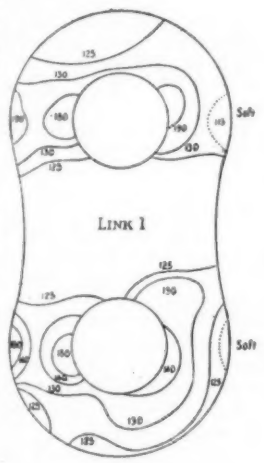


Fig. 14

Stress lines resulting from impact tests; and in an unbroken link of a chain which failed in use

When a specimen of steel is broken the energy is absorbed in producing two effects—(1) separating the crystalline surfaces, and (2) deforming the material in the immediate neighborhood of the rupture. The second depends to some extent on the first, since the higher the stress necessary to effect rupture the greater will be the amount of metal which has been strained beyond its elastic limit. Most crystals possess cleavage planes, which can be separated with very little expenditure of energy once a separation or a crack has been started, and the larger the crystals are the easier it is to effect rupture. The effect of a notch is so to localize the stress in the specimen that a crack starts, and the ease or difficulty with which it extends through the cross-section is measured by the energy or the work necessary to effect complete separation. It is immaterial, therefore, whether this spreading of the crack is performed quickly or slowly. In carbon steels brittleness is almost entirely a question of grain size.

The best shape for the test piece will be the one which reduces the amount of energy spent in deforming the steel to a minimum; for this will bring into greater prominence the energy of rupture, and so cause a greater differentiation between the brittle and tough states.

If a circular bar of steel 1¼-inch diameter is struck a heavy blow in an impact machine, a large amount of energy can be absorbed without breaking it; because the volume of steel which can be deformed is large and the stress is uniform at the outer surfaces. One specimen of a poor quality mild-steel bar absorbed 3,000 foot-lbs. per square inch without breaking. Another bar of the same steel had a circular notch with a radius at the bottom of 1/16-inch cut at the center until the section was reduced to 1-inch diameter, and the energy now absorbed in breaking it was 1,335 foot-lbs. per square inch. A length section of this test is shown in Fig. 11. The volume of steel strained is still considerable, and extends beyond the reduced section into the parts of larger diameter, although the strain is more intense in the neighborhood of the notch. The notch was deepened in the next test to ¾-inch diameter at the reduced section, and this time only 247 foot-lbs. per square inch were required, because the volume of strained material had been considerably reduced, Fig. 12. In this case the deformation does not extend to the outer surfaces of the test at all, and when this takes place the volume has been reduced to the minimum for the type of notch, and there is no object in further reducing the diameter; in fact it is a disadvantage, because it lowers the total energy absorbed, and lessens differences between specimens. If a sharp V-notch is substituted, keeping the reduced diameter the same (¾ inch), the energy absorbed is now 49 foot-lbs. per square inch, and the volume of steel deformed is reduced to very small limits, Fig. 13.

Fig. 15—Illustrating stresses in a crankshaft that failed

This figure, then, is approaching the quantity which is of value in determining the brittleness or otherwise of any material, namely, the energy of rupture along the crystal cleavages. This example shows clearly how the method of hardness curves can be used to show what is happening in an admittedly difficult case of complicated stress hitherto indeterminate.

FAILURE OF MATERIALS.

In conclusion, two cases where the method has been of value in determining the cause of failure may be illustrated:

A burden chain at a large forging press broke, and no fault could be found in the material from which the links were made. It was noticed, however, that the links had elongated slightly round the holes, so an unbroken link was sectioned down the center, and the hardness taken all over the surface. Fig. 14 shows that the link had been considerably overstressed; in fact, the stress at the inner edge of the hole had risen to 18 tons per square inch, instead of the calculated 6 tons. This chain was scrapped and a new chain designed to the new values of the stresses which the chain was subjected to, and this has been working now for over six years without any measurable elongation having taken place.

In the second case a crank-shaft broke through one of the journals, and a thorough examination could not detect any flaw in the steel. It was suspected that a crack had started at the shoulder, owing to the radius being too small at the base, and that this crack had gradually extended under the vibratory stresses until the section was so reduced that complete failure resulted. If this had been the case, then the material behind the creeping crack would not have suffered any severe distortion, but the material which had been forcibly torn asunder when failure took place would show strain hardening. On taking a section as close to the fracture as possible, this was found to be the case, there being an area which possessed the normal hardness of the shaft, and had not been deformed in any way. Obviously this was the area from which the crack originally started. In Fig. 15 (which is not the actual crank, but a reproduction of the same effect for the purposes of this paper) the unstressed area is shown shaded, and each line from this area goes up 10 Brinell units in hardness. The area in the lower half of the figure is a small area where the hardness is low, owing probably to a slight reduction in the carbon at this point in the original ingot from which the shaft was made.

[2]The photographs forming Figs. 9 and 10 of the original are omitted here.

Electrical Phenomena in the Upper Atmosphere—I*

Electrical Phenomena Occurring in the Stratosphere and Above the Levels of Instrumental Observation

By S. Chapman, M.A., D.Sc.

1. It is well known that the properties of the atmosphere are different in important respects above and below a fairly well-defined surface of separation, which is usually situated at a height of about 10 or 15 kilometers from the ground. The layer beneath this surface is called the troposphere, and is characterized by the presence of much convective motion; the temperature in this layer consequently diminishes upwards. In the upper layer, or stratosphere, the temperature shows no systematic variation with height, so that here there must be radiative equilibrium, little disturbed by convective mixing. The stratosphere has been explored to a height of 25 or 30 kilometers by means of *ballons sondes* bearing meteorological instruments.

The electrical phenomena which have so far formed the subject-matter of atmospheric electricity, as ordinarily understood, relate mainly to the troposphere and the lower part of the stratosphere. Such, for instance, are thunderstorms, the surface variations of electric potential gradient, and changes in the ionic content of the air. The electrical phenomena which will be considered in this paper occur at "high" levels above the regions just named—probably above even the greatest heights yet attained by meteorological balloons.

They make themselves apparent in two principal ways. Some of them, though not all, are accompanied by luminosity; this, being observable chiefly towards the polar regions, is known as the aurora polaris. They also produce magnetic effects, which constitute our other source of information. The changes of magnetic force at the earth's surface are continuously recorded at a widely distributed network of observatories. These changes originate mainly in the upper atmosphere, directly or indirectly. The direct part is due to electric currents in the atmosphere, the indirect to secondary currents induced by the former in the conducting earth; the ratio between the two corresponding portions of the magnetic effect at the surface is 2 or 3 to 1. The earth currents flow at greater or lesser depths according to the rapidity with which the external currents vary; those associated with the regular daily magnetic variations flow chiefly at 200 or more kilometers below the surface. At times of magnetic disturbance the changes are much more rapid, and the earth currents do not penetrate so far down; telegraphic engineers know, to their cost, of the enhanced value of the currents in the surface strata at such times. The detailed relations between earth currents and the magnetic variations have not yet been fully elucidated, but the matter cannot be entered upon here, where attention will be confined to the primary phenomena occurring in the atmosphere.

Auroræ and the magnetic variations valuably supplement one another as sources of information of these electrical phenomena. Each affords certain data which are not deducible, or deducible only with difficulty, from the other. On the whole, the magnetic variations from the richer and more available fund of knowledge, since they are observable over the whole accessible portion of the earth, and, moreover, *continuously* observable—by day or night, and independently of the state of the sky. Auroræ, on the other hand, can be seen only over a comparatively limited region, and even there not by day, nor at night when the sky is cloudy or too brightly illuminated by scattered moonlight. Naturally, however, both groups of phenomena have been concurrently investigated, a proceeding assisted by the study of the changes in progress on the sun—i. e. of prominences, sunspots, and other surface features—with which auroræ and the magnetic variations are closely associated.

2. My aim in this paper has been to give a general outline of the subject, without detailed argument or references. The account is not limited to what can be regarded as certain conclusions; without, I hope, departing too far from the basis of observational evidence, conjectural views have also been admitted—a course which seems both the most interesting and appropriate method of dealing with a science of which, as of this, our knowledge is rapidly advancing. For the materials used in this synthesis the writings of many authors have been utilized: particularly, as regards the magnetic variations, the papers of Professor Schuster, Dr. Chree, Mr. Maunder, and Dr. Moos; and as regards auroræ, those of Professors Birkeland, Professor Störmer, and Dr. Vegard. While expressing indebtedness to these investigators, I do not wish to be taken as implying their agreement with all points of the theoretical interpretations here described; some of which are due to these and other writers, while others are independently advanced.

3. The magnetic variations with which we shall be concerned are (*a*) the regular daily variations characteristic of magnetically "quiet" days, and (b) the irregular, intermittent changes associated with magnetic disturbances, which when particularly intense are known as magnetic variation, approximately freed from irregular fluctuations by averaging for several days, consists of two parts: that mentioned under (*a*) together with an additional portion introduced by, and proportional to the intensity of, the existing disturbance. The second portion, or disturbance diurnal variation, represents an inequality in the incidence of disturbance effects round the circles of latitude; the causes which produce it are those responsible for magnetic disturbance, and differ from those which originate the undisturbed or quiet daily variations. Probably no day is completely "quiet" magnetically: in the polar regions of the earth especially, magnetic disturbance is particularly intense and almost always present; here the disturbance daily variation usually considerably exceeds the constant, quiet-day portion. But the two parts of the daily variation can be separated to some extent by comparing the daily changes on quiet and highly disturbed days, and are found to be of quite distinct types. The disturbance daily variation is approximately the same, except in intensity, when derived by comparison of specially quiet days with days of magnetic storm, or with all days.

Both the disturbed and quiet day changes of magnetic force depend on locality, season, and local time. They vary also in intensity—and the disturbance changes vary in frequency—with the state of activity on the sun's surface. The solar activity, the magnetic variations, and auroræ, all manifest the cycle of change which is most familiarly known as the 11-year cycle of sunspot frequency.

The moon, as well as the sun, affects the earth's magnetic field, and there are lunar diurnal magnetic variations, depending on the moon's hour angle (or local lunar time) which are of as great interest as the ordinary solar diurnal variations, though of inferior magnitude.

4. In discussing these phenomena it is convenient to consider the earth as a whole, instead of restricting attention to the sequence of events at one or two localities on it; and to regard it as viewed from the

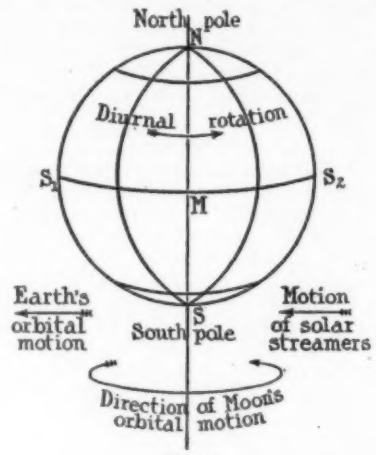


Fig. 1

Illustrating the motions of the earth, moon, and solar streamers as view from the sun (§ 4).
NMS = Noon meridian.
NS_1S = Sunrise meridian.
NS_2S = Sunset meridian.
The day or sunlit hemisphere is directly visible, the night or dark hemisphere is behind; the P.M. and A.M. hemispheres are respectively to the right and left of the noon meridian.

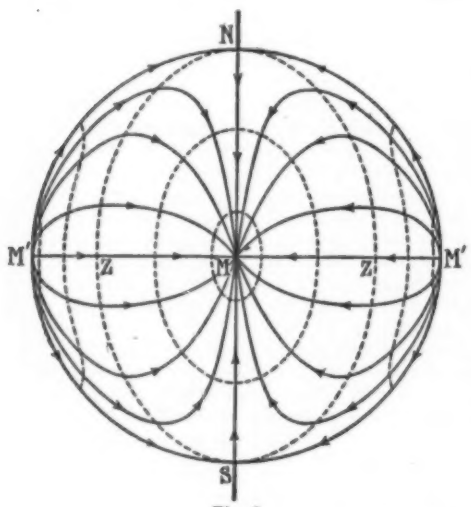


Fig. 2

Lines of equal pressure (dotted) and of instantaneous direction of motion in a tidal system of circulation in the earth's atmosphere, viewed from the tide-producing body (§ 6).
In this drawing there is supposed to be no lag of phase, so that maximum pressure occurs at M_1 and minimum at M'. The opposite side of the earth resembles that shown here. The meridians NZS are lines of zero pressure, separating regions over which the pressure is in excess and defect respectively.

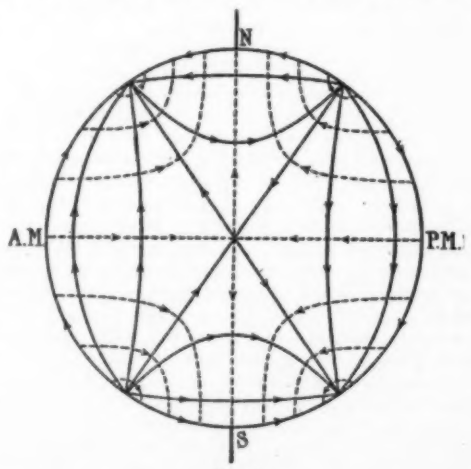


Fig. 4

Current-lines (dotted) and lines of horizontal magnetic force at the earth's surface, corresponding to the disturbance portion of the solar diurnal magnetic variation (§ 10), as viewed from the sun. The complications near to the pole, resulting from the specially high electrical conductivity of the upper atmosphere in the auroral zone, are neglected in this diagram.

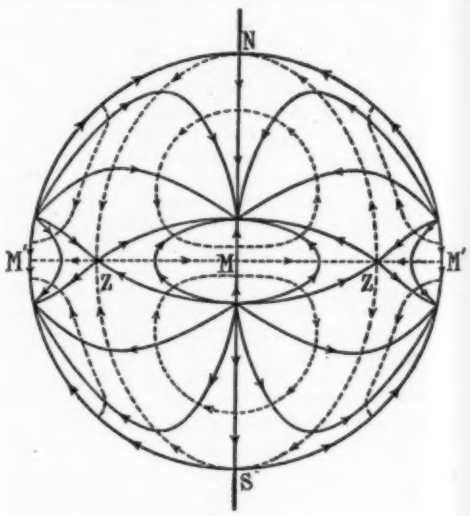


Fig. 3

Electric current-lines (dotted) and lines of horizontal magnetic force at the earth's surface, resulting by electromagnetic induction from the tidal atmospheric circulation of Fig. 2 (§ 6).
The layer in which the electric currents flow is for simplicity assumed to be of uniform conductivity. The obliquity of the magnetic to the geographical axis of the earth is neglected. The above curves give an approximate representation of the semi-diurnal component of the diurnal magnetic variations (except as regards phase), viewed from the sun or moon.

*From *Institution Elect. Engineers* (London).

bodies which govern its magnetic and meteorological changes; that is, from the sun mainly, but in the case of the lunar diurnal variations from the moon also.

The solar and lunar diurnal changes depend principally on the latitude of the station and the local time (neglecting, for the time being, the dependence on the sunspot epoch.) These variables merely define the position of the station relatively to the sun (or, in the case of lunar time, to the moon). Locally regarded, the changes represent the effect of the moving sun, the effect being approximately reproduced at all stations round a given parallel of latitude as the sun "moves round the earth." Viewed from the sun, they appear as the passage of conditions at each station, through stages characteristic of position fixed relative to the sun, as the earth's rotation carries a given station through a succession of such positions. In so far as the earth is symmetrical about its axis of rotation, these stages do not vary throughout the daily revolution, and the changes in any locality depend on latitude and local time, without reference to longitude. The inclination of the magnetic to the geographic axis, however, and the geographical inequalities on the earth, preclude the exact fulfilment of this condition.

From the sun, the earth is seen to be moving along in its orbit from right to left (cf. Fig. 1), and to be turning about its axis so that the front, sunlit, hemisphere is moving from left to right; provided that the observer on the sun is supposed to stand perpendicular to the plane of the earth's orbit, so as to view the North pole of the earth above the South pole. Since the sun itself is turning about its own axis in the same direction as the earth, any emission from its surface which happened to be directed towards the earth would sweep the latter, like water from a fire-hose, from right to left. Again, the moon's orbital motion round the earth is in the same direction as the earth's diurnal rotation.

Over the right-hand half of the earth the sun has "crossed the meridian," and the local time is after noon. This hemisphere will therefore be termed the P.M. (*post meridiem*), and the left-hand the A.M. (*ante meridiem*) hemisphere. Similarly we may speak of the sunlit and dark, or day and night hemispheres, which are separated by the "twilight circle" of the earth. This circle is composed of the sunset and sunrise meridians (on the right and left respectively), which with the noon and midnight meridians (in the plane containing the sun) divide the earth into four equal quadrants.

5. Before describing to what causes the quiet-day and disturbance magnetic variations are due, it is well to exclude explicitly certain possibilities which, though they naturally suggest themselves, are not confirmed on examination. The magnetic variations are not caused by direct magnetic action on the part of the sun or moon; nor do they represent the varying magnetic field of streams of electric charges of one kind, moving separately from chages of the opposite kind, whether within or outside the atmosphere. They are, in fact, variations in the magnetic field of electric currents of the ordinary type flowing in more or less horizontal layers in the upper atmosphere; that is, currents in which the magnetic field is unaccompanied by any appreciable electrostatic field. They are produced, moreover, in essentially the same way as are the currents generated in ordinary commercial power stations, i. e. by electromagnetic induction. In the present instance the earth's permanent magnetic field (the origin of which is still unknown) constitutes the magnetic field of the terrestrial dynamo. The atmosphere, itself in motion owing to various causes, is the armature; while certain layers which are specially ionized (mainly by solar action) are the conductors in which the flow of electric current takes place.

The atmospheric motions concerned are of two kinds, one set being associated with the quiet-day magnetic variations, while the other set is connected with magnetic disturbance. The latter motions originate in and are confined to a region high up in the stratosphere: the former extend throughout the troposphere and a large part of the stratosphere, but are electro-magnetically effective only at a considerable height above the base of the stratosphere. Below this level the air is not sufficiently conducting to allow any appreciable flow of current, so that the irregular convective motions in the troposphere (§ 1) have no part in producing the magnetic variations.

6. The set of atmospheric movements which gives rise to the quiet-day diurnal magnetic variations consists of two great world-wide circulations of tidal type. One is a true tidal motion, due to the moon. The other, of similar character but of different phase and fifteen-fold the amplitude, is of solar origin; it is mainly produced by thermal—not tidal—action. The difference in phase indicates a difference of orientation of the two systems of circulation relative to their governing bodies the sun and moon. Moreover, the orbital motion of the moon causes the lunar tidal system of circulation to shift relative to the solar system, completing one revolution, in the same sense as the earth's diurnal rotation, in a lunar month.

In each case the movement of the air is mainly horizontal. The current-lines in the case of such tidal motions are indicated in Fig. 2, where for simplicity a particular phase, different from that of either the solar or lunar circulations, has been adopted. The maximum velocity occurs at the equator, and in the solar case is approximately 1 kilometer per hour. The velocity is nearly the same at all levels up to a considerable height; the solar diurnal circulation, however, seems not to extend so far up as the lunar circulation: the latter is present in the auroral layer, at a height of 100 kilometers, while the solar diurnal movement does not seem to exist there.

Like all tidal circulations, these two movements are of semi-diurnal type; that is, the motion in either case is the same over the two halves of the earth separated by any meridian plane. The motion being horizontal, the induction takes place across the vertical component of the earth's magnetic force. This component, it should be recalled, is downwards in the Northern, and upwards in the Southern hemisphere, but is otherwise nearly symmetrical with respect to the equator. The induced electromotive force is perpendicular to the direction of horizontal motion, to the left in the Northern, and to the right in the Southern hemisphere.

The systems of electromotive force, like those of atmospheric motion, are semidiurnal (cf. Fig. 3); but the systems of horizontal electric currents impelled by those forces, in the layer which is sufficiently conducting to give scope to them, are not of this type. They are not identical over the two halves of the earth separated by an arbitrarily chosen meridian plane: their intensity is, in fact, much greater over the sunlit than over the dark hemisphere. This is shown by the considerably enhanced activity of the solar and lunar diurnal magnetic variations resulting from these currents, during the hours of solar daylight, and during the season of the year (summer) when, at a given station, the rays of the sun are most directly received. The lunar diurnal magnetic variations exhibit the effect particularly clearly; since the lunar tidal system of circulation progressively advances relative to the sunlit hemisphere (*vide supra*), the lunar hours during which the electromagnetic effect is magnified regress throughout the lunar month; the character of the lunar diurnal magnetic variations consequently changes regularly in the course of a lunation, the activity being greatest during the hours of solar daylight, at each epoch.

Besides this daily and seasonal variation in the intensity of the quiet-day magnetic changes, the latter vary considerably in intensity (while preserving their type almost unaltered) throughout the cycle of solar activity. The one variation indicates a dependence on the position of a station relative to the sun, the other on some intrinsic solar factor affecting the earth as a whole. Both effects are explained by supposing the electric *conductivity* of the layer of air in which the currents flow to vary in the manner described; and that this is because the conductivity is produced by some solar ionizing agent. This agent, as I have shown elsewhere (in a paper communicated to the Cambridge Philosophical Society) is ultra-violet radiation, which must be emitted more strongly at sunspot maximum than at sunspot minimum. It is shielded from the dark hemisphere, but over the sunlit hemisphere it penetrates to a considerable depth in the earth's atmosphere, much below the under limit of the auroral layer (about 100 kilometers above the ground). It seems likely that it is the lower surface of the layer thus ionized by solar radiation which is responsible for bending "wireless" waves round the earth, and so increasing the distance over which messages can be transmitted in this way. Professor G. N. Watson has recently given conclusive proof that, unless prevented by the presence of such a conducting layer, the electric waves would in large part travel outwards into space, instead of, as they are observed to do, round the globe.

The ionization produced by the ultra-violet radiation (which is all absorbed in the atmosphere at a great height above the ground) is most intense over regions which receive the sun's rays vertically, and it diminishes to a low value near the twilight circle and over the dark hemisphere. If the ionization is associated with the production of luminosity, we are prevented from observing the latter owing to the presence of daylight, so that the quiet-day magnetic variations are unaccompanied by any visible atmospheric phenomena. The auroræ are *not* associated with these electromagnetic effects, of whose existence the quiet-day diurnal magnetic variations afford the sole indication.

7. The magnetic variations to which auroræ are related are the magnetic *disturbance* changes, including, of course, the disturbance diurnal variation. As regards the sun, moreover, auroræ are connected with *locally* agitated regions on its surface, instead of to the surface as a whole (whence, it seems probable, there proceeds the æthereal radiation which ionifes the lower conducting layer in the earth's atmosphere, as just described).

Magnetic disturbances and auroræ are produced by the injection into the earth's atmosphere of electric corpuscles projected in confined streams from disturbed regions on the sun. These streams may be emitted in any direction, so far as we know at present; their existence is made known to terrestrial observers only when a stream is projected so that, in the course of the solar rotation, it sweeps over the earth. The streams are often of considerable angular diameter, e. g. 10 degrees or more. As the angular diameter of the earth, viewed from the sun, is only 18.6 seconds of arc, it becomes completely enveloped in the streams; and often remains so for hours or even days, notwithstanding that the relative speed of the streams at the distance of the earth enables them to sweep right across the earth in 35 seconds. The latter fact explains why magnetic storms, the particularly intense and world-wide disturbances which occur when the earth is enveloped in a dense solar stream, are observed to commence at almost the same instant all over the earth. Again, since disturbed regions on the sun often continue to emit streams of electric corpuscles in the same relative direction for a period of more than one solar rotation, a given stream may traverse the earth more than once. This accounts for the observed tendency for magnetic conditions to recur after an interval equal to the time taken by a stream to reach the earth again, after a complete rotation with the sun. This, which is shown by quiet, no less than by disturbed conditions (corresponding respectively to the absence and presence of streams in the earth's neighborhood) is only a tendency and not a definite periodicity: for the sequence of streams existing at any given time is continually being interrupted by the cessation, or alteration of direction, of old streams, and the initiation of new ones.

8. The streams seem to consist entirely or predominantly of corpuscles having the same sign of electric charge. They are ejected from the sun with a speed comparable with that of light, and travel outwards approximately in straight lines. When they approach the earth, however, their rectilinear motion becomes modified owing to their entry into the earth's magnetic field. A magnetic field, of course, exerts a force on a moving electric charge, perpendicular to the plane containing the direction of the magnetic force at the point instantaneously occupied by the charge, and to the line of motion of the charge. In a uniform magnetic field an electric charge will, in general, describe a spiral path, the axis of the helix lying along the direction of the magnetic force. In the earth's field, which is uniform neither in direction nor in intensity, the motion of the solar corpuscles is more complicated, and the problem of calculating their paths has not yet been completely worked out. Some important results have, however, been arrived at. It appears that, though in an intense stream the particles seem to impinge upon the atmosphere from all sides, there is a strong tendency for them to be drawn in towards the earth's magnetic poles; yet not so as to fall most numerously at the magnetic poles themselves, but rather around two zones, one centered at each such pole. The radius of the zones can be calculated approximately, but depends upon the nature and speed of the particles. The zones are naturally identified with the zones of maximum auroral frequency; these are centered as described, and have a radius of about 20 degrees. This is much greater than the radius calculated on the assumption that the solar corpuscles are β-particles (i. e. negative electrons, having a mass much less than that of a hydrogen atom, though travelling with great speed). On the other hand, the observed agrees pretty closely with the calculated radius, if the particles are supposed to be α-particles, positively charged, but otherwise identical with ordinary atoms of helium moving with great velocity.

9. Three principal consequences follow from the injection of the solar corpuscles into the earth's atmosphere. First, the particles break up many of the molecules which they encounter before being brought to relative rest in the atmosphere. This means that the layer in which the retardation takes place is ionized; during times of magnetic disturbance, therefore, there are two conducting layers instead of only one.

)*Continued on page* 202)

© Underwood & Underwood
Lifting a bundle of cork from the vat where it has been boiled to soften it and to remove the tannic acid. From here the cork goes to the scrapers (see frontispiece)

A big cork yard near Almoriama, in southern Spain. The boy and the burro bring water and wine to the workmen, and carry away the baled cork; a bale lies handy all wired for loading

Preparing Cork for Shipment

Views Illustrating Treatment of Cork in Spain Before Shipping It to Supply Our $6,000,000 Industry

ALTHOUGH we have had beers and wines and higher drinks banished from our midst their places will be filled and must be filled by other bottled liquids, and bottles must have stoppers of some kind. There is, therefore, no danger that our needs for that ancient standby, cork, will do other than increase as the years to come pass over our heads. Our illustrations this week plan to show how our annual importations of cork are prepared for shipment.

Cork, as its name implies (Sp. *corcha*, Lat. *cortex*, or Lat. *quercus*) is the outer layer of the bark of a certain oak (*Quercus suber*), evergreen in habit, flourishing in southern Europe and generally along the North African coasts. This cork oak is principally under cultivation in Spain and Portugal whence about 70 per cent of the world's supply is secured. The cork oak does not develop its first yield of cork bark until it is 15 or 20 years old. At this age the first stripping from the trees is made, the yield is rough and unequal in value and is used only for tanneries or as rough rustic finishes. After 8 more years the second stripping of cork bark is made, resulting in material fit for floats, etc. Strippings are made every 8 or 10 years thereafter, the quality improving steadily until the trees die of old age at about 150 years or even older. Of course the bark must be carefully removed that the tender young regenerating layer inside may not be injured. The stripping takes place as follows: During July and August careful girdling cuts are made, one near the ground and the other just below the main branches, and several longitudinal cuts run between the two girdlers. With wedges the outer corky bark is carefully pried away in as long and perfect slabs as possible, and these slabs are then removed to the "yard" where they are stacked for treatment. Our right-hand view at the top of this page shows a "cork yard" with its picturesque workers in action.

The first step in preparing the cork bark at the "yard" is to steep or boil it in great vats. Our upper left-hand view shows a bundle of rough cork being lifted from the boiling vat. This boiling softens and loosens the rough woody outside and also dissolves the contained tannic acids. The bark is made more elastic and tends to flatten from the curved state in which it came from the tree. Thus it becomes easier to handle and to scrape. After sufficient boiling and steeping the cork slabs go to the scraping and baling shed. Our frontispiece (p. 193) shows such a shed, with a baling press in the foreground. We have noticed that these sheds are all rather crude roofs of cork slabs supported by a rough frame work of poles; no unnecessary expense is incurred, the best of sun shade materials being right at hand the workman uses it for his roof. The soaked slabs, piled in a conveniently slanted manner, the row of workers attack the rough outside surface of the bark with peculiar dished semicircular bladed hoe-handled scrapers. It appears to be a back-breaking labor, this scraping of the cork slabs, but then in Spain it still has its material compensations as suggested by the load of jugs which the boy and burro are seen bringing in at the right of our third view above. After the scrapers have removed the rough woody layer, the resulting clean smooth sheet of cork is sometimes heated over a fire again, this time to char the surface as well as to aid in flattening it. The charring seals the pores of the bark and lends it the quality called "nerve."

After scraping and charring the bark is packed on burros and carried to the coast towns where there are sorting yards. In these yards the cork slabs are replied and carefully sorted according to grades of fineness and perfection. Then they are finally baled or packed for export. One of the last steps is the trimming of the slabs into even shapes suitable for safe baling. The photograph on the opposite page shows the trimmers at work in another portion of what seems to be the same "yard" shown in the photographs at the top of this page. A finished bale bound with wire is seen at the right of the last view.

We find a multitude of uses for all forms of cork and the United States has 60 factories employed in making over our annual import of $3,500,000 of raw cork into finished products of an estimated value of $6,000,000.

We use cork in a multitude of ways. Among the earliest uses are as shoe soles and as stoppers for wine bottles. The ancient Greeks and Romans knew the value of cork as an insulating material, Pliny relating the use of cork soles by ladies, and Horace in one of his odes (iii. 8) recording its use as stoppers for wine-containers. Of course it could not have been used for glass bottles before the 15th century, A. D., and it would seem not to have been generally employed in that manner before the 17th century. The extreme lightness and resistance to waterlogging must have been discovered many centuries before the event related by Plutarch, who says that a messenger used a cork float as an aid in swimming the Tiber when Rome was besieged by the Gauls in 400 B. C.

Among the modern uses distinct from the classic ones we find as interesting ones the use of very thin sheets cemented between silk to form the waterproof fabric of waterproof coats, the tips of cigarettes, the heat-proof ingredient of floor coverings, the sealing part of tin caps for beverage bottles, grips for bicycle handles, golf-club handles and the like.

Origin of Spectra

FROM the results of Bergen Davis and Goucher, combined with those of other investigators, it would appear to be generally agreed that with the vapors of such elements as Hg, Zn, Cd, and Mg, for example, the actual ionisation potentials are given by $V e = (1.5, S) \times h$, where (1.5, S) is the frequency of the shortest wave-length of the principal singlet series $v = (1.5, S) + (m, P)$. It would also appear to be established that it is possible to cause a vapor bombarded in a vacuum by electrons to emit a radiation consisting of one wave-length only, provided *all* the bombarding electrons possess kinetic energy given by the quantum relation $Ve = hv$, v being the frequency of the monochromatic radiation stimulated; moreover, by gradually increasing the speed of the bombarding electrons the vapor may be caused to emit at successive stages radiation of shorter and shorter wave-lengths, each particular wave-length being stimulated only when the bombarding electrons have attained velocities corresponding to its frequency as indicated by the quantum relation. All apparent departures from this view obtained in any experiments would appear to be explainable when account is taken of the fact that a Maxwellian distribution of velocities holds for streams of electrons thermionically emitted by incandescent metallic filaments. Detailed descriptions are given of a fluorite spectograph and of a vacuum grating spectograph, the first allowing measurements to be made as far as $\lambda 1400$ and the second serving for the chumann region as far as $\lambda 600$ or a little beyond.—J. C. MCLENNAN (*Guthrie Lecture*).

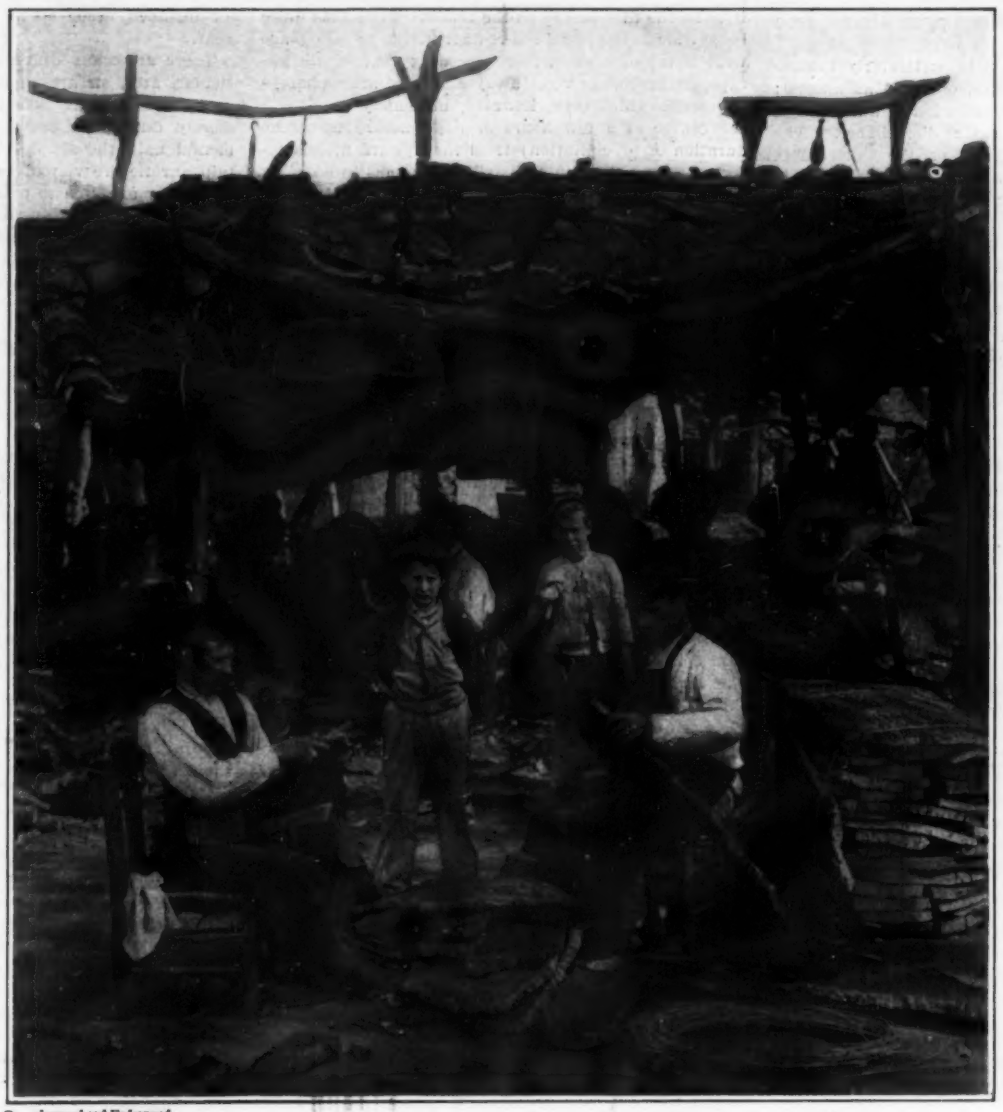
Power from Tidal Waters*

An ingenious scheme for harnessing the tidal waters of two or more rivers to obtain a continuous supply of electrical power has been evolved by Mr. J. Smith of J. Smith & Co., engineers, Glasgow. For this purpose Mr. Smith proposes to construct a dam across each river, and install hydro-electric power plant which would be operated by the flow of water from one side to the other side of the dams. There must also be a definite time relationship between the tides of the rivers. Considering one of the rivers at high tide with the dam gates open, the water would be at the levels A, B in Fig. 1. The dam gates are then closed, and at half tide, three hours later, the water will be at the levels A, C. The water turbines are now started, and the flow of water through the turbines is adjusted so that for the next three hours the power plant is driven at constant head, the water finally reaching the levels D, E. It is then necessary quickly to adjust the water during the turning of the tides to the levels F, E by opening all the sluice gates of the dams. The gates are then closed, and in the next three hours the water will rise on the sea side to level B—Fig. 2. The water turbines can then again be operated at constant head for three hours, while the water rises from the levels B, C to the levels D, E. The dam gates are then opened and water must then pass quickly to the river side of the dam, so that the river is raised to level F, which corresponds to high tide. The operations just described would then be repeated, and it will be seen that the turbines for the one river can be worked at a constant head equal to half the rise and fall of the river for three hours from half tide to low tide, and again from half tide to full tide. Considering now the second river, it is chosen with its tide lagging or leading the tides of the first river by three hours, so that the idle periods of the plant installed on the first river correspond to the working periods of the plant on the second river. Therefore, by choosing the rivers so that the tidal powers are approximately equal, a continuous supply of power can be obtained, the two sets of generators being connected to one system of high-tension mains and working in parallel during the change-over periods.

As an example of the magnitude of the power involved in these tidal waters, we may cite the figures given for a scheme utilizing the river Severn, the river Dee, the Menai Straits and the river Mersey. The rise and fall of the river Severn at Portishead is taken as 34 ft., and, as explained, only half that fall—17 ft.—is used, the other half making the head which is kept during the whole time the turbines are working. The volume of water used at this head is 74.5 miles in length by one mile broad by 17 ft. deep. The amount of water constantly passing over the fall for three hours averages 187,921,251 cubic feet per minute, and allowing for the efficiency of the turbine, this corresponds to approximately 4,770,000 horse-power. Turning to the other rivers, the river Dee, the Menai Straits, and the river Mersey would be grouped together to supply power alternately with the river Severn. In the case of the Dee, North Wales, which has 28 ft. rise and fall, a constant head of 14 ft. is ensured. The volume of water used at this head during the three hours' run—approximately 15 miles long by 4 miles broad by 14 ft. deep—will average 123,099,300 cubic feet per minute. As regards the Menai Straits, a head of 14 ft. of water is again available, with an average displacement of 47,687,733 cubic feet per minute. Finally, for the Mersey, where the tide is 26 ft., there is a constant head of 13 ft. of water, and there, it is stated, the water displaced is 99,977,710 cubic feet per minute, corresponding to an average mileage of 40 miles long by 1 mile broad by 13 ft. deep. Consequently the total power to be obtained from the group will average 5,650,000 horse-power. The continuous horse-power is therefore 4.77 millions for the river Severn and 5.65 millions for the river Mersey group, but it is suggested that the mean value, 5,210,000 horse-power, could be maintained continuously by arranging the larger capacity plant to assist the smaller unit. There appears to be a certain flexibility in the system on account of the surplus water available at each end of the working period of the turbines. The Mersey is taken as 3 hours 50 minutes behind the Severn at high water and 50 minutes behind the Dee and the Menai Straits.

We understand this scheme has been submitted for consideration to the Water Board Committee of the Board of Trade. Assuming that such large rivers could be employed for this purpose and that the scheme is quite feasible, it is claimed that the average cost per horse-power of plant and cables installed would be somewhat less than £17—about half the figure recently given for the development of the waterways in Scotland—and that the cost of electrical energy would be comparable with that obtaining in countries possessing large hydro-electric installations.

*From *The Engineer* (London).



© Underwood and Underwood

Trimming the cork slabs that they may bale neatly. The slabs often break in the course of removal from tree and during scraping

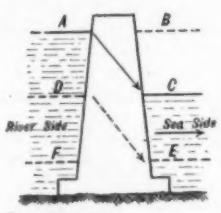


Fig. 1

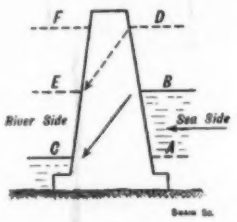
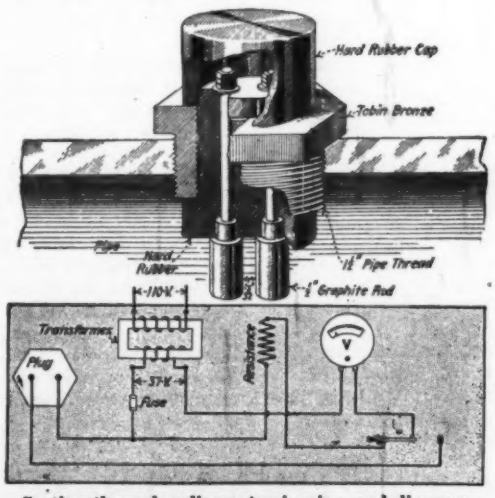


Fig. 2

A scheme to harness the power latent in tidal rivers



Section through salinometer in pipe, and diagram of electric connection

Salinometer for Power-Plant Use

By H. S. Knowlton

An exploration company is using an electric salinometer, illustrated in the accompanying diagram, for testing boiler-feed water and checking the leakage of condenser tubes. The apparatus consists mainly of a plug with two graphite electrodes, which is inserted in the feed-water piping, the carbons being mounted at the bottom of a hard-rubber block through which metal terminal rods are run to binding posts at the top, inclosed by a hard rubber cap. A transformer reducing the potential to 37 volts from the ordinary 110-volt service is provided with a voltmeter and resistance for comparing the drop across the salinometer terminals with previous calibrations.—*Power* (New York).

Constitution of the Earth's Interior

R. D. Oldham's synopsis of discussion at British Assoc.: Three distinct divisions are recognizable in the earth's interior: (1) The outer solid crust of high permanent rigidity and of thicknesses ½ to 1 per cent. of the radius, but subject, from unknown causes, to mass movements and deformations in which displacements of as much as 10 miles vertically and 100 miles horizontally have occurred. (2) A shell about half the thickness of the radius with high rigidity for stresses of duration up to the order of tidal action, but of low rigidity to long-continued stress, at least in the outer portion. (3) A central nucleus of low rigidity for stresses of even a few seconds' duration. The data for conclusions (2) and (3) are derived entirely from records of earthquake waves, which show that the transition from (1) to (2) is sufficiently abrupt to reflect elastic waves, while that from (2) to (3) is far more gradual, and lies at a distance from the earth's center of 0.4 to 0.5 of the radius.—*Science Abstracts.*

Electrical Phenomena in the Upper Atmosphere

(*Continued from page* 199)

Secondly, where the ionization is particularly intense it is accompanied by luminosity, observed as auroræ; this accounts for the polar distribution of auroræ, and their association with magnetic disturbance. The production of the latter depends on the third effect mentioned, viz., the electrification of the air. This is accompanied by electrostatic forces of sufficient intensity to impart an important degree of motion to the extremely rarefied air. This is the second of the two types of motion referred to in § 3.

The general nature of the movement can be readily inferred. The mutual repulsion of the entangled charge spread over the world-wide spherical layer produces an upward, outward movement, as in a charged soap-bubble. Thus the air travels vertically upwards—except during the first few minutes of a magnetic storm. For at first the downward momentum of the injected particles depresses the air, before the electricity has accumulated sufficiently to reverse the motion.

In the process of electromagnetic induction the vertical movement acts by cutting across the horizontal component of the earth's magnetic force. Since the latter is directed from North to South, the upward motion induces an electromotive force from East to West, while the initial downward velocity induces one in the opposite sense. An electric current flowing from West to East, as in the latter case, will increase the horizontal magnetic force at the earth's surface; this is what is usually observed in middle and lower latitudes during the first few minutes of a magnetic storm. Afterwards the reversal of motion of the air, and of the resulting electromotive force, causes a diminution in the horizontal magnetic force; this is one of the most characteristic features of magnetic storms.

10. The electromagnetic effects of a storm are not quite of the simple type which might be expected from the remarks of § 9. The complication arises mainly from the unequal distribution of the corpuscular injection. This inequality is not altogether due to the deflection of the particles by the earth's magnetic field; in part it is due to the circumstances of emission from the sun. Over any given region near the auroral zone, for instance, visual observation of the auroræ strongly suggests that the injection is both "patchy" and intermittent.

This causes the ionization of the air to vary considerably from place to place, and the inequalities of conductivity thus set up are likely to endure for some hours. Consequently, even if the electromotive force were quite uniform in direction and intensity, the current-flow would be far from uniform. As the inequalities of conductivity are probably greatest in the polar regions, we have an explanation of why the magnetic disturbances in those parts are specially irregular. The great *intensity* of disturbance there is due to the high average value of corpuscular injection and ionization around the poles. I have found evidence, which will be discussed in a future paper, that the conductivity in the "maximum auroral zone" is particularly intense.

Besides these comparatively small-scale inequalities of precipitation and conductivity, the study of the disturbance portion of the diurnal magnetic variations (which represents the inequality of disturbance round the circles of latitude) shows that the solar corpuscles fall more intensely over the P.M. than over the A.M. hemisphere. Thus the two solar ionizing agents have different "most favored hemispheres"—the sunlit one being that most affected by the other agent, the ultra-violet wave radiation.

This longitudinal inequality of conductivity in the auroral layer (here regarded as extending all round the globe, whether or not luminous effects are visible) shows itself in the production of a greater diminution of the horizontal magnetic force, in middle and equatorial latitudes, over the P.M. than over the A.M. half of the earth. This appears clearly from the disturbance diurnal variation of horizontal magnetic force in the latitudes mentioned (cf. Fig. 4); it would necessitate too long a digression to explain how the disturbance diurnal variation in the other magnetic "elements" and in other latitudes likewise indicates the existence of excessive precipitation of corpuscles over the P.M. hemisphere and round the "auroral maximum" zone.

11. One interesting circumstance connected with the non-uniform injection of charge is that, while it results in the existence of inequalities of electrical conductivity over the spherical layer affected, the charge itself is continuously re-distributed so as to keep the surface density of electrification practically uniform. This is true, of course, of any spherical electrified shell of sufficient (though not necessarily uniform) conductivity. In the case before us the conductivity seems quite large enough to permit the re-distribution to take place with a rapidity altogether exceeding that of the escape of the charge right away from the atmosphere—an escape which does, however, ultimately result (in the course of a few hours or days, according to the duration of precipitation) from the upward motion referred to in § 9. The re-distribution seems to be of an oscillatory character, and so to be accompanied by the propagation into space of Hertzian waves of wave-length approximately equal to the diameter of the earth. The period of these waves is about one-twentieth of a second.

The surface density of charge thus being maintained uniform over the earth, the upward electrostatic force tending to produce the vertical motion of the air is likewise uniform. The vertical motion itself, however, will not be uniform, since it will be unequally resisted by the mechanical force acting downwards on the induced currents, tending to prevent their production. This mechanical force is proportional to the intensity of the horizontal currents and of the horizontal component of the earth's magnetic force. The latter is least at the poles and greatest at the equator, while the former is probably greatest in the auroral zone. It is therefore not very easy to estimate the distribution of the vertical motion over the layer.

One further circumstance in this connection deserves mention: the precipitation of electric charge into the atmosphere does not produce an "electric storm" at the earth's surface, as well as a magnetic storm (or minor magnetic disturbance). During a world-wide magnetic storm, indeed, in which the extension of the corpuscularly ionized layer all round the earth permits a uniform re-distribution of the charge, no change in the electrostatic field at the earth's surface would be expected—for a charge on the outside of a conductor does not produce any electric force in its interior. But even in the case of a minor disturbance, due to a stream of corpuscles which falls upon, and renders conducting, only a limited portion of the upper atmosphere, no electrostatic change at the earth's surface is observable. This seems to be owing to the electric shielding effected by the other ionized layer, which extends all round the earth (though it is most conducting over the sunlit hemisphere). This layer is lower than the other, so that local charges in the auroral layer do not electrically affect the interior of the "diurnal variations" layer (§ 5).

The grounds for the conclusion that the latter is lower than the auroral layer may be briefly described here.* If the solar semi-diurnal atmospheric circulation, which is produced by thermal action at or near the earth's surface, extended up into the auroral layer, the conductivity existing there at times of magnetic disturbance would permit an increased induction of "diurnal variation currents" at such times. In particular, the semi-diurnal component of the solar diurnal magnetic changes should be increased; this is not found to occur, the modification in these changes due to disturbed conditions being of quite different type (cf. Figs. 3 and 4). The lunar atmospheric tide, on the contrary, is produced by forces acting on each portion of the air throughout its whole extent, so that it should extend higher up than the solar diurnal circulation; and this is confirmed by the fact that the lunar semidiurnal magnetic variation *is* increased at times of disturbance. Hence the layer in which the quiet-day magnetic changes are produced must be lower than the auroral layer. Assuming that the latter is situated at approximately the same height in all latitudes (i. e. that the penetrating power of the corpuscles is independent of the latitude to which they are deflected), the former layer may be ascribed to a lower level than 100 kilometers.

12. Before proceeding to consider the physical nature of the solar corpuscles, and their connection with the ultra-violet light which ionizes the lower conducting layer of the atmosphere, some of the principal features of auroræ must be touched on.

The existence of a zone of maximum auroral frequency round each pole of the earth's magnetic axis, and of radius about twenty degrees, has already been mentioned. Near these zones auroræ are visible on almost every night on which the conditions of seeing are suitable. When specially intense streams of corpuscles are in the earth's neighborhood, however, precipitation of intensity sufficient to produce luminosity occurs over a more extended region. At such times, which are marked by the occurrence of unusually violent magnetic disturbance, i. e. by magnetic storms, auroræ are observed over a large range of latitude, simultaneously in each hemisphere. Occasions on which auroræ are thus visible so far south as London, for instance, occur on an average about six times a year.

There are many different forms of auroræ—in particular, arcs, streamers, curtains and coronæ. But it seems not unlikely that all, or nearly all, these are merely different aspects of aggregations of one elemental unit, the simple streamer or ray. When curtain auroræ are viewed from a point directly beneath them they are seen to consist of a thin wavy and discontinuous series of vertical streamers. The auroral corona appears to be formed of a rather different arrangement of similar rays. This unity of composition agrees with the evidence of height determinations (which show that all types of auroræ are situated at approximately the same level) in indicating that there is no essential physical difference between the various forms. The lower limit of height is 100 kilometers above the ground, very nearly, in all cases. Vegard states that no auroræ has been certainly proved to extend downwards below a height of 95 kilometers. The great majority lie between 100 and 130 kilometers, and within this range there are two well-marked levels of maximum frequency of occurrence, corresponding to lower limits of 100 and 106 kilometers. This indicates that the solar corpuscles probably fall into two homogeneous groups, travelling with rather different speeds and therefore having different powers of penetration. The heights named do not seem to vary with latitude, or from year to year; thus the degree of activity on the solar surface does not affect the nature and speed, but only the intensity and frequency, of corpuscular emission from the sun.

13. There is a tendency for the brightest part of auroral bands and rays to occur at their lower edge, though in the case of rays it is occasionally found some distance above this level. The fact has a bearing on the question as to the precise nature of the solar particles, and confirms Vegard's hypothesis that they are α-particles, as the radius of the maximum auroral zone has already suggested (§ 8). Such particles, of molecular mass, are found to penetrate to a definite distance when projected into a gas; they travel in practically straight lines for this distance and then come to a relatively dead stop when their velocity is reduced to that of the surrounding molecules. The ionization (and luminosity, if such is produced) is greatest shortly before they reach their limit of penetration. These features, as we have seen, are manifested by auroræ, and are quite distinct from those which characterize the projection of negative electrons, β-particles, into a gas. Moreover, a stream of α-particles has much greater power than has a stream of β-particles of being projected intact in free space to a great distance; for the charge on an α-particle is only twice that of a β-particle, while the momentum of the α-particle is far greater than that of the other. It is thus better able to resist the dispersing influence of the electrostatic repulsion mutually exerted by the members of a stream of particles all of one sign of charge. A further argument tending to the same conclusion rests upon the explanation which has been given of the increase in the earth's horizontal magnetic force during the first few minutes of a magnetic storm. This (§ 9) was attributed to the downward momentum of the injected particles, and the fact that the momentum is able to manifest itself in this way is much less surprising if the particles are as heavy as helium atoms than if they are mere negative electrons.

(*To be continued*)

*They are given more fully in a paper communicated to the Cambridge Philosophical Society, December 1918.

Benjamin Franklin and Daylight Saving

It has often been remarked that "there is nothing new under the face of the sun," and the *Electrical World* has unearthed an interesting example of the truth of this precept. It appears that the real originator of daylight saving was Benjamin Franklin, who in 1784 contributed an anonymous communication to the *Journal of Paris*, written in a characteristically philosophic and witty manner. He suggested that every morning all bells in churches should be rung at sunrise (or, if this did not suffice, cannon fired), and he further suggested a tax on all windows with shutters, a spartan rationing in the candles allowed to each household, and the prohibition of travelling by coach after sunset, except those of physicians, surgeons and midwives. There was no gas or electricity then available to illustrate the saving to be accomplished, but Franklin entered into a calculation of the amount of wax and tallow normally burned in Paris between March 20 and September 20 and anticipated an annual saving of expenditure in the neighborhood of four million pounds. He also did not fail to point out the hygienic advantages of working solely by daylight instead of by the "smoky, unwholesome and enormously expensive light of candles."—*The Electrician* (London).

Monistic and Dualistic Conceptions of the Stellar Universe*

By C. V. L. Charlier, Observatory of Lund, Lund, Sweden

1. THE last ten years have brought about the gradual development of two diametrically opposed ideas in regard to our stellar universe—ideas which may be fitly characterized by the distinction implied in the title of this article. According to the monistic conception, the stellar universe is thought of as a single system, which, if not really in equilibrium, is well on the road to such a state. Others maintain that the stellar system can be better explained as a mixture of two systems, which are in the process of blending, the one with the other, and giving birth to a stellar universe which is far from being in what we should call in mechanics a stable state of distribution. It is asserted by both sides that they have established their opinions upon facts; and, in truth, the interpretation of the latter is so intricte that we are able, in many instances, (to use them) to support first one and then the other hypothesis.

For Herschel and the astronomers of the last century the monistic point of view was the natural point of view. It was only when Kapteyn in 1904 set forth his celebrated theory of two star streams, that we seriously doubted the monistic conception of the stellar universe and demanded if it was adequate. In truth this hypothesis of Kapteyn seemed to explain in a simple way the anomalies in the proper motions of the stars to which Kobold some years before had directed the attention of astronomers. However, only three years after that, we find Schwartzschild showing that the same phenomena might be explained without giving up the monistic conception. He, nevertheless, was unable to prove that his hypothesis was superior to that of Kapteyn.

Since then each new discovery in stellar astronomy—and there have been many recently, especially in the field of stellar spectroscopy—has been discussed from the point of view of one or the other of the two hypotheses.

It is justifiable first to say that the monistic conception has been recently revived and its foundations strengthened by the relation which has been established between the motions of stars and the kinetic theory of gases which has been developed by Clausius and Maxwell. This analogy was first suggested by Sir William Thomson (Lord Kelvin). But Poincaré (in his *Hypothèses cosmogoniques*, 1911) was the first to really try to apply the kinetic theory to the stars. He was not concerned there, however, with the fundamental problem in connection with the kinetic theory—in knowing the frequency of the distribution of stellar velocities. The problem has been approached more recently by Halm and Jeans and the writer, who has furthermore made great use of the kinetic theory in the lectures which he has given at Lund during the last two years.

The main idea in the kinetic theory is the following: Consider a group of stars made up of a great number—some millions of single ones. The motion of one individual star is governed by the attraction of the others according to Newton's law. It is evidently impossible to consider *exactly* the attraction of each of the stars, partly because the work would be overwhelming on account of the calculation, and partly because we never know, and never will be able to know, with sufficient precision the relative position and the velocity of the stars. Therefore, we approach the problem in another way. The attraction of each individual star depends apparently, for the most part, upon the attraction of the *whole* of the group. The distances between the stars are great, and the orbit of an individual is, at least for a long time, the same as that of a particle moving in a field of force having at all points the same potential as the entire group. If the density of distribution of the stars and of the distribution of velocities at each point of the group remains unaltered, the system may be said to be in *dynamical* equilibrium. If this equilibrium does not exist, the density of distribution varies from time to time.

Even in the case of very diffuse groups of stars we cannot be sure that the star under consideration will not pass from time to time, though perhaps at very long intervals, very near to another star so that its orbit will be suddenly and completely changed. Since the influence of these passages—in the kinetic theory of gases they are called collisions—cannot be analyzed by means of ordinary mechanics, we study it by the theory of probabilities. The result is the kinetic theory, known also as "statistical mechanics." This theory shows that the passages in the course of time, smooth out the differences in the velocities of the stars, until at last an equilibrium—a *statistical* equilibrium—may be reached. The velocities in each part of the group are then distributed according to Maxwell's law.

Another important question is that connected with the mixture of stars of different masses. Here an *equipartition of energy* is produced, such that the product of the mass of a star by the square of its velocity is, on the average, the same for stars of all sizes. Thus, in the long run, the most massive stars have the smallest, while the smallest ones acquire the greatest mean velocities.

Let us pass now from the kinetic theory to the comparison of the monistic and dualistic theories of the universe. In the following table I have collected the principal problems which the two theories have tried to explain and have added a short description of the solution:

Problem.	Monistic theory.	Dualistic Theory.
1. *State of motion*	The universe is almost in *dynamical* equilibrium and is constantly approaching *statistical* equilibrium.	Neither dynamical nor statistical equilibrium.
2. *Distribution of velocity of Stars.*	Generalized ellipsoidal theory resulting from the kinetic theory.	Two (perhaps more) star streams.
3. *Form of the Milky Way.*	(Ellipsoid of revolution.)	Spiral or irregular.
4. *Speed and Spectral type.*	The mean speed depends upon the *masses* of the stars (mv^2 constant).	The speed increases with the *age* of the stars.
5. *Development of a star.*	(meteoric dust) red, yellow, red stars (M. white yellow, K. G. F. A. B. A. F. G. K. M.)	(nebulous gas) white yellow, red stars, (B. A. F. G. K. M).

The discussion of the five problems of the preceding table would be too long for an article in this journal, so I shall limit myself to the first one. In a general way I will give all the arguments in favor of the kinetic theory, and discuss the objections which have been made to its application to the stellar universe. The most important of these have been made by Jeans, Eddington and Poincaré, and I will discuss them here in their order.

2. *Jean's Objection*: The stellar universe may be in statistical equilibrium, and, in that case, also in dynamical equilibrium; or it may be only in dynamical equilibrium, or, according to the dualistic theory, it need be in neither dynamical nor statistical equilibrium. It is evident from the proper motions of the stars that it is not in statistical equilibrium. We shall see later, nevertheless, that it is manfestly approaching that state. In regard to the two other possibilities, the question was studied in 1915 by Jeans. The result of his researches was that "star streams, such as we have observed in the universe, do not seem to be in accord with the supposition, that our universe is in a stable state." Accepting the dualistic theory, I examined the problem at the same time as Jeans, in my lectures in 1915, and arrived at the opposite conclusion. To be more precise, I obtained the same mathematical (and mechanical) result as Jeans, but we differ in regard to the application to the astronomical problem. As far as I can see, this is the explanation. For a stable state it is necessary—as a mathematical analysis shows—for the ellipsoid of velocity to be a spheroid whose axis of revolution is perpendicular to the radius vector drawn from the center of the universe. The observations show in fact that the surface of velocity is approximately an ellipsoid of revolution. What is the angle between the axis or revolution, and the radius vector from the center? We may have different opinions upon this point, in consequence of the difficulty which exists in determining the position of the center. Mr. Jeans thinks that this axis is directed towards the center (agreeing with Turner) while according to my opinion it is *approximately* (but not exactly) perpendicular to the radius vector as the theory demands. Since my determination of the center of the universe, from the distribution of helium stars (June 1916) was not known to Mr. Jeans at the date of the publication of his article (December 1915), I hope that he will find some reasons to modify his conclusions upon this point.

3. Let us now see to what extent we can accept the hypothesis that the universe is really on the road to a state of statistical equilibrium. This question has also been dealt with by Jeans, who, as the author of *La théorie dynamique des gaz*—the best treatise on the kinetic theory known to the author—is a peculiarly competent authority upon the subject. In order to measure the velocity with which a disturbed gas reaches a stable state, Maxwell made use of a quantity which he called the "relaxation time." The greater this time, the slower is the restoration to the stable state by the collisions of particles. It should be noted that the time necessary to establish (approximately) a statistical equilibrium is always greater than the "relaxation time," but one may consider the two times as being of the same order of magnitude. For gases, the time is of the order of 10^{-10} seconds. For stars, Jeans found the enormous value of 10^{34} years. Applying Newton's law to the problem (instead of Maxwell's law of repulsion, which Jeans used) I found the value 10^{10} years for the same quality—a value of the same order of magnitude as Jeans. In other words, this shows that it would take the stellar universe some billions of years to arrive at statistical equilibrium by the collisions of stars. Jeans thinks this time too long "even for astronomy," and concludes that "there can be no question of a universe similar to ours arriving at a final stable state like that which the theory of gases has made us acquainted." Without doubt the period is very long and exceeds all our previous ideas as to the age of the stars. But have these ideas a foundation of sufficient accuracy? Have we taken scrupulous account of the phenomena of radiation? I think not. In any case, it may be wise to examine the facts showing the influence of these collisions of stars upon the distribution of their velocities.

4. And indeed, facts of this kind are not lacking. In the following table, from Gyllenberg, are given the semi-axes of the ellipsoids of velocity.

SEMI-AXES OF THE ELLIPSOIDS OF VELOCITY OF STARS OF DIFFERENT SPECTRAL TYPE.

Color	Type	a_1	a_2	a_3	Ω
White stars	B & A	1.73	3.10	2.73	4.48
Yellow "	F & G	3.02	4.95	3.67	6.86
Red "	K & M	4.00	4.51	4.27	7.39

The figures represent siriometers per stellar year, the siriometer being equal to 10^6 astronomical units, and the stellar year being equal to 10^6 years. The axis a_1 is (approximately) directed to the center of the Milky Way; the axis a_2 is perpendicular to it in the Milky Way (toward the Vertex), and the axis a_3 is directed toward the pole of the Milky Way. Various researches made by Ludendorff, Shapley and others point to the conclusion that it is probable that the white stars have the greatest mass; next come the yellow, and the red ones have the smallest mass. Considering all these points we find:

1. The mean velocities (Ω) of the stars are proportionally greater as the masses of the stars are small, which agrees with the law of equipartition of energy in the kinetic theory.

2. The largest axis a_2 is approximately perpendicular to the radius vector drawn from the center.

3. The other axes (a_1 and a_3) are, at least for the yellow and red stars, almost of equal length, so that the ellipsoid of velocity is a spheroid, located (almost) in the position necessary for dynamical equilibrium.

4. For the smallest stars (red) the three axes of the ellipsoid of velocity are almost of the same length, showing that these stars are already, at least approximately, in statistical equilibrium.

This seems to show that the "relaxation time" in a group of stars is proportional to the mass of the latter.

These considerations are, indeed, purely provisional, for a separation of spectral types here taken together (B & A, F & G, etc.), is necessary before one can undertake a conclusive discussion. (Thus the ellipsoids of velocity of B type stars differ essentially from those of A type stars.) In any case, the preceding considerations seem to indicate that the "relaxation time," long as it may be, has already left some recognizable traces in the history of our stellar universe.

(To be concluded)

*Translated by Miss E. W. Wickham, from *Scientia* 1917, and her ereprinted from *Pop. Astron.*

Prime Mover of High Efficiency—I*

The Still Engine, Which Combines the Advantages of Steam with Those of Internal Combustion

By Frank E. D. Acland, M.Inst.C.E.

THE reconstruction of industry, and the reparation of the damage and waste of war, are occupying, and must long continue to occupy, the serious attention of the civilized world. Economy and efficiency are the basis of prosperity, and industry will depend more than before on technical and scientific workers to ease its burdens, shorten its hours of labor, and raise the living standard of those engaged in it. This country has shown in the past, and still shows, that it possesses technical and scientific ability second to none; but it often gives scant encouragement to new developments or new principles, until competitors in other lands have proved them of practical utility and profit. At the same time the expenditure of energy and capital on new things, whose underlying principles are intrinsically unsound, is incalculable.

The necessity for the conservation and economical use of fuel by every means is at last fully recognized by the Government; but every man, in all branches of technical and scientific work, hopes that "freedom, self-determination and progress" will not be smothered by too many committees and Government officials.

The interim report on electric supply, issued last year by the Coal Conservation Committee (Appendix A.), estimates a coal consumption of 5 lb. per h.p. hour (about 4 per cent thermal efficiency) as being a reasonable average consumption for the horse-power used in the country in factories, mines, and railways, and suggests that by the substitution of general electrification it might be reduced to 1½ lb. (about 12 per cent efficiency). The improvement of the efficiency of the prime movers which supply the power seems even more important than the method of its distribution and application. If the fuel efficiency claimed in that report for electrification can be doubled, the saving of coal consumed per annum in these industries alone would amount to 68 million tons for the same output of energy.

There are two methods of producing power by the combustion of fuel—either under boilers or within the main cylinders of combustion engines. The greater part of the world's power is still derived from steam, which, owing to its proved reliability and greater adaptability to the services demanded of it, holds the field in competition with its rival—the internal-combustion engine. The steam engine exerts powerful starting efforts; puts trains or other masses into motion; operates at any speed from start to its designed maximum; can develop more than its rated power at reduced speed; can carry severe overloads for long periods, and generally gives ample warning before ceasing to operate: but this is accomplished with a loss of 80 per cent, at least, of the heat energy contained in the fuel supplied to it—a loss which is irrecoverable.

The internal-combustion engine shows a far higher heat efficiency, but cannot start itself without some external source of power; cannot develop its full power except at full speed; is a poor performer at low speeds; can only operate on moderate overloads for short periods; and may cease to operate, owing to a small defect, without warning; so combustion engines have as yet made little progress in competition with steam in locomotive work, and have supplanted steam but to a limited extent in marine and stationary engines.

The conversion of heat into useful work, with the minimum of waste, depends on the efficiency of the means employed, that is to say, it depends on the losses in the heat cycle, and on the losses in the mechanism employed for producing the heat and converting it into power.

"The efficiency of a heat engine is the ratio of the heat converted into mechanical work to the total amount of heat which enters the engine." So we are taught, and we owe to our teachers a mass of accurate information about the laws of thermodynamics, thermal and ideal cycles, which serve as standards of comparison for every kind of heat engine; but they do little more than point out the way to getting the most out of the heat in an ideal engine, and ignore the losses in the creation and supply of the heat, or in the machine which converts it into mechanical work. It by no means follows that an engine, which thermodynamically attains the highest indicated efficiency in relation to the ideal, is in practice the most efficient for its purpose, or the most economical in fuel. Efficiency from the user's point of view is the ratio of the useful work to the total heat in the fuel used.

Fig. 1 shows the brake thermal efficiencies of various types of prime movers—steam, gas, and liquid fuel, with the fuel consumption in lbs. per shaft horse-power hour, based on a calorific value of 14,000 B.T.U.s per lb. for coal, 18,000 B.T.U.s for liquid fuel. The mechanical efficiencies of the various engines, and heat efficiencies of the boiler and producer, when not expressly stated in the reports of the trials, are assumed to be as shown.

Comparing the cycle of steam with that of combustion engine, the latter has two great advantages over the former. The fuel which imparts the heat to the working fluid is introduced directly into its working cylinder, and the temperatures and pressures are far above the limits of those possible in the steam engine and boiler.

COMPARATIVE EFFICIENCIES OF PRIME MOVERS.

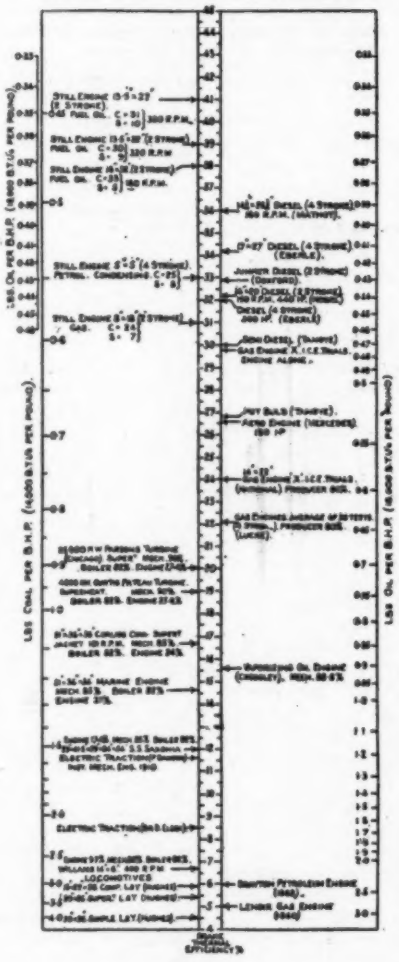


Fig. 1

The steam engine suffers from heavy heat losses in the creation of its heat; it is forced to work at comparatively low temperatures and pressures, and with superheating, compounding and condensing added to it, has arrived at a point where further efficiency is well-nigh impossible.

Sir Dugald Clerk, in his paper submitted to the Royal Society of Arts in March, compared the thermal efficiency of the gas engine—28 per cent—with an efficient producer, with that of the largest and best of existing steam turbines—18.5 per cent—referred to the coal consumption under the boiler, and alluded to the probability of great improvements in gas engine efficiencies. The further recovery of thermal loss in the steam engine, or in the mechanism, is a difficult, if not an almost impossible task. In the internal-combustion engine all the losses at present existing are capable of some recovery, and certainly of considerable reduction.

The maximum ideal efficiency of a heat engine is obtained where the difference existing between the highest and lowest temperatures of the working fluid is greatest in proportion to the maximum temperature, and here the internal-combustion engine, with an initial temperature higher than the furnace temperature of the boiler, and even higher than the melting-point of cast iron, is capable of realizing better thermal conditions than any other form of heat engine; but in its turn it suffers from two disadvantages—it ejects its working fluid at a temperature too high for ideal conditions, and it loses heat energy to a regrettable extent in the cooling of its cylinder.

The result obtained in practice from the two cycles separately, based on their best performances after half a century of intensive development, is that in the steam engine there is a loss of over 80 per cent of the heat contained in the fuel, and in the combustion engine of 60 per cent.

The recovery and efficient use of the waste has been the work of many years of patient research by William Joseph Still and others associated with him, and has resulted in the design and construction of a variety of engines which bear out the correctness of his principles, and point to a vast field of further practical application.

The possibility of combining in one engine the superior thermal cycle at the high temperatures and pressures of the combustion engine with the low thermal cycle of steam to deal with its rejected heat, and, in the same engine, to add the superior working advantages of the steam engine, was the basis of his work.

The development of the internal-combustion engine has included many proposals and attempts to utilize the heat going to waste in the exhaust and cooling water; but while in existing engines some proportion of the heat can be usefully recovered as steam from the exhaust gases, the cooling water from the jacket is of little value, owing to its low temperature, and the efficiency of the engine itself is not augmented. If, however, the temperature of the cooling water could be maintained at that of steam at useful pressure, the efficiency of the engine would be improved and the weight of steam be usefully increased.

It has been inadvisable during the past four and a half years to allow publication, but the time has arrived when the principles of this new development should be available for examination and discussion, and an account be given of some of the results achieved. The delays and difficulties during the past few years can only be fully appreciated by those who have taken an active share in meeting, and to some extent successfully overcoming them; but it will be evident from the summary which follows that the results already obtained from engines which are admittedly experimental types, constructed under disadvantageous conditions, are sufficiently remarkable to substantiate their claim to be of real importance, while they give promise of far wider application and further improvement in the drawing offices and shops of great manufacturing concerns.

THE STILL ENGINE.

The Still engine is an engine capable of using, in its main working cylinder, any form of liquid or gaseous fuel hitherto employed; it makes use of the recoverable heat which passes through the surfaces of the combustion cylinder, as well as into the exhaust gases, for the evaporation of steam, which steam is expanded in the combustion cylinder itself on one side of the main piston, the combustion stroke acting on the other side. It increases the power of the engine, and reduces the consumption of the fuel per horse-power developed.

Its primary object is not to use the waste heat for raising steam, but first to use it in improving the thermal conditions of the working cylinder, and so ensure the maximum efficiency from the fuel burnt within it, diminishing, as a consequence, the heat lost in that operation. Since the maximum efficiency is obtained by combustion of the fuel in the cylinder, and the minimum by the evaporation of the water in the steam generator, it is evident that the larger the quantity of steam which can be generated per horse-power developed by the combustion cycle, the lower must be the heat efficiency of the whole machine.

Internal-combustion engines are kept cool by the circulation of cold water round their cylinders; the heat thus absorbed causes a rise in temperature of the water as it travels through the jacket, so that the cylinder is subjected to temperature differences and heat stresses, which are an abiding source of trouble and difficulty to the designer.

In the Still engine (Fig. 3) the jacket and cooling water form part of the circulating system of a steam generator, which may be an integral part of the en-

*Read before the Royal Society of Arts, May 26, 1919.

gine, or external to it. The cooling water therefore enters and leaves the jacket at a constant temperature, regulated by the pressure of the steam; the cooling being effected by converting the water into steam without raising its temperature. Excluding the radiation losses, which are kept low by lagging, all the heat which passes through the walls is thus usefully recovered in the water as steam. The temperature of the cylinder wall is uniform over the whole of its exterior surface, and the heat lost to the cooling water at each stage of the cycle—compression, combustion, and expansion—is diminished.

During compression, owing to the walls being at steam temperature, the incoming charge picks up heat, instead of losing it, during the greater part of the stroke, an advantage of the greatest value to the heavy oil types of Still engines, where an air charge is taken in at the full outstroke, and is compressed to a pressure where its increased temperature ensures the certain ignition and combustion of the fuel which is injected into it.

During combustion and expansion, the uniform and higher mean temperature of the walls reduces the heat lost to the jacket water. Some of the heat thus economized adds to the useful work on the piston, the balance passing out in the exhaust gases for recovery.

To ensure the maintenance, in a practical and reliable manner, of the temperature conditions which produce this efficiency during the combustion cycle, a departure from the design and construction of the cylinders of normal internal-combustion engines is imperative; they have hitherto been made of cast iron, of a thickness sufficient to resist the working and thermal stresses thrown upon them, including occasional heavy loads caused by pre-ignition of the explosive charge. With these thick walls or liners, the temperature difference between their inner and outer surfaces, which is essential if the surplus heat is to be carried off, can only be obtained safely by the circulation of water at low temperature through the jacket; this is especially the case in cylinders of considerable diameter, or capable of high power per swept volume.

The cylinder of a Still engine consists of an inner liner, which is approximately one-third to one-fourth of the usual thickness; it is ribbed externally so as to add to its conducting surface and provide suitable passage for the cooling water, and it is reinforced by an outer hoop capable of withstanding the highest pressures to be met with in working. The stresses due, in ordinary practice, to the cold water at the inlet, and the hotter water at the outlet, are suppressed in the Still cylinder, the cooling water being at a controlled and uniform temperature throughout (Fig. 2).

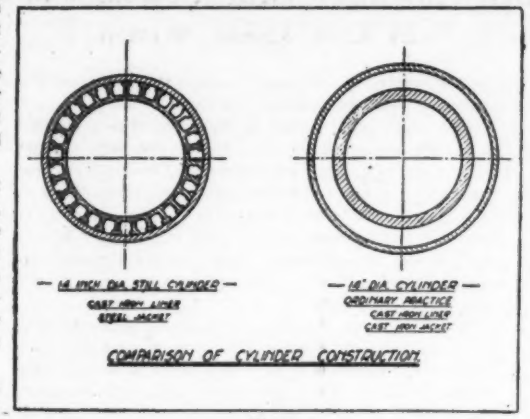


Fig. 2

No failure of a cylinder of any kind has occurred, even under most severe, even abnormal test conditions, *e. g.* with mean combustion pressures of 180 lb. per square inch in a two-stroke engine, to which was added overload steam mean pressures of 70 lb., *i. e.* a total m.e.p. per revolution of 250 lb. per square inch.

STEAM FROM WASTE HEAT.

In gas and oil engines of constant volume and constant pressure types, the combined losses in radiation —cooling water and exhaust gases—range between 75 per cent and 65 per cent. The highest indicated thermal efficiency claimed under test conditions with a Diesel engine—Mathot—300 b.h.p., four-stroke at three-quarter load, is 47 per cent (36 per cent brake efficiency). If 4 per cent is allowed for radiation, 49 per cent of the total heat is available for recovery, and if 10 per cent efficiency is assumed for the steam cycle, the brake thermal efficiency of an engine giving this high result would be raised by 10 per cent of 49 = 4.9, i. e. 36 + 4.9 = 41 per cent; but there is no reason why the steam generated and used under the conditions of the Still system, should be limited to so low a figure. Fifteen per cent seems a more reasonable assumption, and even a higher figure may be anticipated, in which case a brake thermal efficiency of 44 per cent should be possible in a complete installation. Such a statement can only be warranted by realizing the method by which steam is produced and used in this engine.

Jacket.—The Still engine may be of the constant volume or constant pressure type, or a combination of both; its losses to the cooling water are not the same as in a normal engine of either type, except in so far that they vary with the type, with the cycle, with the efficiency of the combustion stroke, and with the load. At normal and full loads, such heat units, in a Still engine, as pass into the jacket water, which is at steam temperature and pressure, are lessened and are wholly recovered without loss—radiation excluded—in overcoming the latent heat of the water and give off their steam in the steam space in proportion to the heat flow at those loads. At lower loads less steam is produced, until at still lower loads no steam at all is measurable. In other words, the jacket losses are practically eliminated.

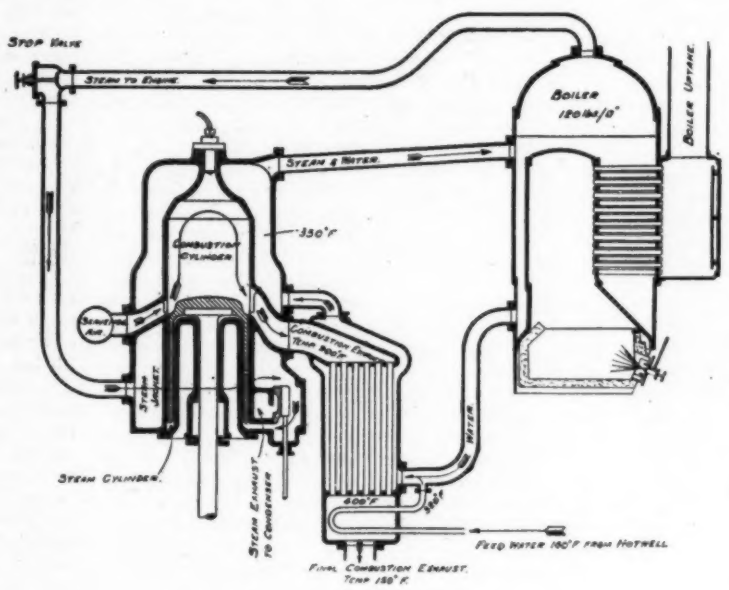


Fig. 3

The exhaust gases take a subsidiary, but important part in the cycle; their usefulness in ordinary combustion engines, in raising steam, is limited to the amount of heat recoverable between the initial temperature of the exhaust and that of, say 50°F. above the steam temperature, after which the whole volume passes away to atmosphere at a still useful temperature, less a small percentage available for feed-water heating. But in the Still engine, the exhaust gases, after raising their quantum of steam, are employed in preheating all the water required for the steam generated in the jacket water and in the generator. Trials at full efficiency over long periods and steady loads, show terminal stack temperatures as low as 150°F. The heat efficiency of the combined cycles is therefore exceedingly good, with an initial temperature of over 2,000°F., and a final exhaust to atmosphere at 150°F.

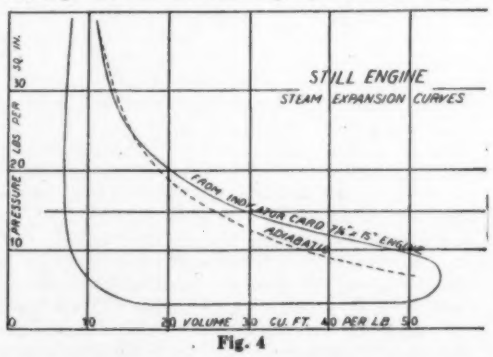


Fig. 4

The quantity of steam capable of being generated from "waste heat," depends upon the efficiency of the combustion stroke, are at a higher temperature than experimental work prove that the weight of steam recovered may vary from a maximum of about 7 lb. per b.h.p. hour, developed by the combustion cycle of a four-stroke constant volume engine, at full load, to a minimum at light loads which is hardly measurable, and which only balances the loss due to radiation.

Steam: Use.—The steam thus recovered is a by-product, is limited in amount, and its value depends upon the efficiency of its employment. This is carried out in a logical manner. In place of being expanded in external auxiliary engines, with their thermal and mechanical losses, it is returned to the combustion cylinders of the Still engine, and is expanded on the opposite side of its main piston, one stroke being performed by steam and the other by combustion.

The piston and cylinder walls, pre-heated by the combustion's stroke, are at a higher temperature than the steam when it is admitted and while it is being expanded; there is, therefore, no loss from condensation, and the steam exhausts at a slight superheat above the normal expansion temperature, a condition which is unattainable in any form of steam engine without direct loss of energy (Fig. 4). With an early cut off, it can be expanded economically right out to atmospheric pressure, or below it, and be either recompressed (Stumpf cycle) or exhausted to condenser. The steam, during expansion, forms an efficient means of cooling the piston.

It may be convenient, at this point, to interpolate a few lines on condensing and compounding, either wholly in the Still engine itself, or in external high-pressure cylinders compounding to low-pressure Still cylinders on the same shaft. These separate high pressure and intermediate pressure cylinders will meet special conditions, and have been found of utility where manœuvring or starting in any position is required for single or twin combustion cylinder sets; but a better arrangement in multiple cylinder sets of Still engines is to use the high pressure steam in one of the cylinders at the back of the piston, and compound into similar adjacent cylinders. Many variations of these arrangements suggest themselves. The steam is usually exhausted to a condenser, but it can, in special cases, be employed in low-pressure turbines, or made use of in connection with producer gas auxiliaries.

The effect of the steam in its coöperation with and re-action on the combustion cycle, has been the subject of many series of exhaustive tests, carried out in the early stages of the development of the engine, and subsequently on many other engines, of which the following *résumé* may be of interest.

The engine used for this research was of constant volume type, four-stroke. It first underwent a series of tests, so as to arrive at its "initial horse-power" as an explosion engine, *i. e.* without any power added by the steam cycle, and was carefully checked in this connection by comparison with well-known and authenticated trials carried out by the late Professor Bertram Hopkinson, F.R.S., and others. Though it was a single cylinder unit with automatic inlet valves, its "initial horse-power" was rated on a par with the power given by four cylinder sets with mechanically operated valves deduced from tests over very short periods, under their best conditions.

The quantity of steam generated per "initial brake horse-power" from the jacket alone, averaged 3.28 lb. per b.h.p. hour, and from the jacket and exhaust together 6 lb. per b.h.p. hour, this being the average of the whole of the trials over periods varying from twenty minutes to over six hours. The final six hours of a seven and a half hours continued test, gave a total recovery of 6.9 lb. of steam per initial b.h.p. A whole series of these early trials was carried out under the supervision of C. Vernon Boys, F.R.S., whose sympathetic interest and encouragement is gratefully acknowledged as having largely contributed to the progress made since the inception of the system.

(*To be continued*)

Aluminum Alloy

An alloy especially suitable for pistons of internal combustion engines consists of aluminum 91% or more, copper 4.5—6%, nickel 0.5—0.8%, zinc 0.8—1.2%, antimony 0.7—1.0%. The aluminum is of ordinary commercial purity containing, for instance, from 0.5% —0.9% of iron, and preferably less than 0.1% each of manganese, magnesium, and tin.—T. H. B.

Copernicus*

A Rare Account of the Life and Work of the Great Originator of Modern Heliocentric Astronomy

By Albert Durrant Watson

HIS EARLY LIFE.

WHEN the merchants of northern Europe heard that Captain Columbus, a sailor of Genoa, had found a western sea-road to India, they feared the failure of their trade in the markets of Spain as a result of the inflow of products from the new Eldorado. One youth of twenty-one years viewed the discovery from a different angle. He had recently returned from Krakau (Cracow) where, under the inspiring tuition of Albert Brudzewski (1445-1497), his studies in mathematics had given him new and permanent impulse and direction, and fitted him for his astronomical career.

This youth was Nocolai Koppernigk, or as we know him, Nicholas Copernicus (1473-1543). He saw that the most effective bar to the world's progress was not the ocean vastness, nor the threat of the hurricane that drives the courageous ship to its doom. He perceived that, though the mind is man's greatest instrument of freedom, yet in the mind are man's real barriers. The fixed idea, the closed incident, imitation that kills initiative action, the unchangeable creed and the unoriginal method—these he recognized as our most insuperable limitations—in a word, those self-paralyzing mental attitudes of inertia, ultra-conservatism, fear and skepticism which lure the indolent to Circean Isles of unreality.

Ptolemy, a learned Alexandrian of the second century, as interpreted by Johann Müller of Königsberg (1436-1476), (or, as he styled himself, Joannes de Monteregio, but now known as Regiomontanus), was the acknowledged authority in that world that Copernicus knew, in all things astronomical. From a very early date in the career of the young mathematician, he distrusted the findings of his mathematical mentors. He was not willing to accept the poetry of the Scriptures,

"The earth also is established that it cannot be moved,"

as the working principle in the science of a new age. The heavens were telling him a different story from which a poetry of even more sublime significance would yet be inspired.

Was Nicholas Copernicus a Teuton or a Slav, a German or a Pole? His father was a Pole, his mother a German. His allegiance was Polish, his language was German. A German citizen, but a Polish subject, his education was cosmopolitan. As Shakespeare was "not of an age but of all time," so Copernicus was not of one race only but of all humanity.

Born February 19, 1473, in the fortress town of Thorn, one of the bridge-heads of the Vistula in Prussian Poland, Copernicus was destined by his father for a commercial career, but Destiny itself intervened, the father died when his boy was only ten years of age, and his mother's brother, Lucas Watzelrode, became the faithful, wise and efficient guardian of Nicolai and his elder brother Andreas.

Lucas Watzelrode was an eminent scholar, having studied at the universities of Cracow, Leipsic and Prague. In his guardianship of the young Koppernigks, their mother's dearest hope was realized. She rightly esteemed her brother, rising, as he was, through his scholarship, to eminence and great influence, as a most desirable foster-father of the orphaned boys. This feeling was greatly strengthened when, six years later, he was advanced to the vacant Bishopric of Ermland.

At the university of Cracow (1491-1494), Copernicus had probably the best mathematical teacher in Northern Europe. But eminent as was the teacher, the scholar was far greater, and today we hear of Brudzewski only because, over four hundred years ago, for three seasons, he had for a scholar, a boy named Nicolai Koppernigk.

For leisure, Copernicus, at this time, practised drawing, and even made a portrait of himself, using a mirror the while to demonstrate his subject. This portrait was preserved for many years, by those who cherished his memory and his fame, but it perished long ago with many other important matters pertaining to his life and fortunes. Its last owner was Tycho Brahe. It was destroyed by fire in 1597.

It appears that Copernicus never intended to take his degree at Cracow. Just why he returned to his home in 1494 does not transpire. A canonry of Frauenburg Cathedral was vacant at this time, and an effort was made to have him appointed, but the Roman curia named another for the office, and Copernicus entered the University of Bologna as a student of canon law, attending also the lectures of Novara in astronomy.

Here, with his brother Andreas, he was compelled to borrow money on the security of his uncle's name, and at ruinous rates of interest. These loans were honorably secured and as honorably and promptly paid. This loan seems to have been necessary in view of the circumstances; indeed, Copernicus is almost monotonously noble. He deliberately determined that his life should exclude all that was unworthy, and the resolution was rigidly kept.

In 1497, the recently appointed canon of the Frauenburg, conveniently vacated the office, having died that year, and Copernicus was nominated and appointed to succeed him. From this time, while still pursuing his studies in Italy, he gave occasional lectures on mathematics to brilliant Roman audiences. In 1501, he obtained further leave to pursue his studies, and turned to Padua where he entered the medical school and sought diligently to master the healing art.

Thus was Copernicus a mathematician, a doctor of canon law, a doctor of medicine, a secular canon of the church, and incidentally, though most important of all, an astronomer. It is interesting to note how some men find roads to greatness through many avenues of expression. We think of Michelangelo, of Leonardo da Vinci, of Goethe, of Lorenzo de Medici, and wonder if it is not true that the higher the mountain, the wider its base and the greater the number of rivers flowing from their sources in its slopes and canyons.

The medical skill of Copernicus was ever at the command of the poorest in his town. Occasionally he was called to attend the rich, and once, at least, his services were called into requisition at court, where, we are told, the patient recovered. An early and curious law forbade the practice of medicine by ecclesiastics. This canon law was now obsolete as to the medical part of the doctor's duties. It was not permitted, however, that any sacred office should be exercised by one who engaged in the use of the scalpel or the cautery. These practices were adjudged to have the effect of hardening the heart, hence the prohibition.

The astronomical attainments of Copernicus were supposed to fit him peculiarly for the practice of the healing art. The common belief attributed a more powerful action of certain drugs to special planetary conjunctions. Every zodiacal constellation had its peculiar influence on a certain part of the body. The effects of remedies depended upon the position of the moon in the zodiac.

It is assumed that because Copernicus copied more than once a prescription whose numerous and varied ingredients would remind one of the contents of the witches' cauldron, he therefore probably used it. I doubt the correctness of this inference. I fancy the remarkable prescription was kept as a curio with which to regale his friends, all of whom, no doubt, could appreciate a joke. Moreover, whatever the nature of his prescriptions, the patients of Copernicus had a happy habit of making a good recovery.

It helps if a man or woman is born at the right time. During the youth of Copernicus, whether unnoticed or acclaimed by the thunders of fame, many personal forces were beginning to move the world. Gutenberg (1398-1468) had introduced his movable plates and printing press. The Tudor period had begun in England. The stormy period of the Medici in Florence was for the moment tranquilized under the beneficent tyranny of Lorenzo the Magnificent, that notable patron of art and letters. Michelangelo and Leonardo painted their wonderful frescoes and chiseled the forms of their genius out of stone while Savonarola thundered his eloquent warnings from the pulpit of San Marco. In the midst of it all Martin Luther stood in the Diet of Worms solemnly declaring: *"Hier stehe ich; ich kann nicht anders."* All the while civilization was under the mighty spell of that outstanding fact, that Columbus had broken through the last barrier of the old world and found a new hemisphere.

Before this great seething cauldron of the new age—the new learning, the new navigation, the new religion—stood Copernicus, as resurgent as any.

We are too ready to regard the ancients as crude without any other reason than the fact that they were ancient. The Hebrew poetry pictured a four-cornered flat earth around which a spherical star-studded sky revolved. Pythagoras, Philolaus, Anaxagoras, Hietatis and others had spoken of the round earth and other spheres, making many prophetic guesses at the truth, and often very nearly hitting the mark. The system described by Ptolemy in his *Almagest* was very complicated, requiring more than sixty circles to explain it, but it was very cleverly worked out. Based on what was known by astronomers at the time, the Ptolemaic scheme was most ingenious. It had been accepted for nearly fourteen centuries and was hard to supplant.

Some minds are hospitable to complexity. Others demand the simplicity of generalization. The former is often dominated by detail, the latter by law or principle. But complexity is nearly always somewhere involved within the generalization no matter how true the principle may be. To our finite minds, some details seem ever to remain unexplained. Perhaps he is happiest who can with simple faith accept the thought of

"One law, one faith, one element,
And one far off divine event
To which the whole creation moves."

The heliocentric system was not a complete explanation of the heavens. Copernicus failed to divine the elliptical orbit and had still to resort to thirty-four epicycles to explain his view. It remained for Kepler to introduce the discovery of the ellipse before supreme order could be said to reign in our mathematical concept of the skies.

COPERNICUS AT HEILSBERG.

Returning to our story, we find Copernicus, having studied at three universities (Cracow, Bologna, Padua), receiving his degree at a fourth, in the Episcopal palace at Ferrara in 1503. After two further years in Italy, at thirty-two years of age, he returned to Ermland and engaged in political life, as the records of certain assemblages show. By resolution of the chapter dated January 7, 1507, he was appointed permanent physician to the bishop, at whose Episcopal residence, the castle of Heilsberg, he remained a member of the household till his uncle's death in 1512.

Heilsberg is 46 miles from Frauenburg. From the rather formidable looking castle walls are seen the rivers Alle and Simser, which wind their tortuous courses till lost in extensive forests of oak and beech with which the country is well wooded. Heilsberg Castle in those days was like the stronghold of a mediaeval prince. The open court was thronged with a motley crowd of ecclesiastics, pages, servingmen, jugglers, minstrels, clowns, and other retainers. The times were perilous. The bishop's charge was no sinecure. Messengers were constantly bringing tidings of some new outrage; grave churchmen with weighty spiritual matters sought their solution; young noblemen with ambitions, and mendicants with their humbler plaints sought help of the good bishop. Every sort of society was represented in this throng.

At noon a great bell tolled the signal for the midday meal. Thereupon, a procession led by the bishop in full choir-costume, attended by vicar, chief justice, chaplain, chamberlain, marshal, guests and retainers in order, led the way through the courtyard, to the great banqueting hall. Eight tables were spread; for, of the eight different degrees of dignity, each had his place fixed by authority. The buffoons and jugglers occupied a conspicuous central position so that all might enjoy their sallies.

For six years, Copernicus was daily a member of this procession and assemblage. As days and months passed, he must have shared more and more, at first as confidante, and later, no doubt, as occasional adviser, the burdens, anxieties and obligations of the government of Ermland with which his uncle, the bishop was charged. The latter was at once prince of the empire and vassal of Poland. He was, *ex officio*, a member of the Polish senate and vice-regent of the Polish king in west Prussia. Poland and Prussia each sought his defence against any encroachments on its rights by the aggressive action of the other.

Ermland was the only one of four Prussian dioceses which preserved its independence. Thus the bishop of Ermland ruled a little state. He was required to conciliate, and yet hold in check, three neighbors, all mutually hostile, some of them powerful and ambitious, all restless, and one of them, at least, discontented. Thus the task of the bishop was almost an impossible one. Besides, Bishop Watzelrode was not much of a politician. He had energy and probity, but was strenuous without being supple and resourceful. Though

*From *Jour. Roy. Astron. Soc. Canada* (Toronto).

his designs were all admirable and well-meant, they generally failed.

Copernicus and his uncle were seldom apart. They not only dwelt together, they travelled together. When the bishop went abroad to Petrikau, to Thorn, to Cracow, to diets, conferences, or royal solemnities, his nephew was his trusted companion. On the occasion of one of these journeys prolonged for two months, Copernicus found time to translate from the Greek of Theophylactus Simoncatta, a Byzantine writer, the first work of a Greek author to be printed in Poland. This was published in Cracow. Dr. Leopold Prowe thinks the work betrays more enthusiasm for Greek culture than of proficiency in Greek scholarship. We should not forget that classic Greek was still a language little known and possibly the only persons in the north who knew more of it than Copernicus were the famous trio of Oxford[1]

It was during his residence in the castle of Heilsberg that Copernicus laid the foundations of his new thought of a heliocentric astronomy. While he was in Padua, the theories of Pythagoras had been freely discussed, and his mind had been opened to a keener scrutiny of the accepted teaching of his day. It is difficult for us to realize how interesting the Pythagoreans must have been to those who first questioned the canons of Ptolemy. To these ancients, the planets, the moon, and the spheres all revolved around a central fire from which the sun received its light and reflected it on us. They had learned that the light of the moon was reflected. They supposed that the sciences of music and of numbers were intimately involved in the movements of the heavenly luminaries. They combined their astronomical and their musical systems in the celebrated teaching of "the music of the spheres." The velocities of the moving bodies depended on their distances from their central fire, the slower and nearer bodies giving out a deeper and the swifter a higher note. Meanwhile we cannot hear spheric music because we hear it always and are never in a position to contrast it with silence.

While by no means accepting all the Pythagorean doctrines, Copernicus acknowledged that they gave him his first hint of the true hypothesis. He returned from Italy with a mind which could never again accept the geocentric as opposed to the heliocentric system. His own conception as presented in *De Revolutionibus* seems to have been, in the first place, an inspiration from the Greeks rather than the result of observations. These latter, he hardly began to make till 1513, after his return to Frauenburg, and he was never a very accurate observer, accuracy not being necessary for his larger purpose.

In March, 1512, the bishop was bidden to the wedding-feast of the King of Poland. Copernicus accompanied, but for some unknown reason did not return to Heilsberg with his uncle. The bishop was taken ill on his way home and died three days after his arrival, at the age of 64 years. This was on March 29, 1512. Andreas, the brother of Copernicus, was seized meanwhile with leprosy and died before 1519.

ADMINISTRATOR AT FRAUENBURG.

Upon the death of his uncle, Copernicus returned to Frauenburg, and though he never took orders as a priest, he administered the functions of his office, whether sacred or secular, with conscientious diligence and dignity. His stipend was equal to $4,250. This with the income from another source, for he was also commissary of the diocese of Ermland, was sufficient to maintain in easy financial circumstances one with his simple tastes.

Through the dust and clouds of four centuries we see again the cathedral of Frauenburg with its six towers surrounded by walls and bastions rising from a commanding eminence near the town. Externally somewhat frowning, it has a restful interior. A monument has been erected in the cathedral bearing the inscription:

Astronomo celeberrimo, cujus nomen gloria utrumque implevit orbem.

The administrative duties of Copernicus were somewhat harassing. The conflict of the new learning with the old was raging, and its battles, we are told, did not always end without bloodshed, being complicated with political, racial and national animosities such as still disturb the peace of central Europe. Doubtless Copernicus held himself as aloof as possible from these unseemly disorders, but he had a great admiration for classical antiquity which set him fairly with those who furthered the revival of learning. Nevertheless, his mind was independent, being animated, but not enslaved, by its classical enthusiasms.

We may be sure that, amid all his worries, Copernicus was not careless of his dream. His soul was too much exalted in its vision, his spirit too fine in its fiber, to permit his ordinary duties, either temporal or ecclesiastical, to dim to darkness the rays of his life's central luminary. All permanent progress is made, all great achievements are consummated as a result of clear thinking and intense feeling.

> A dream is stronger than a battle host;
> A thought well turned may beat an empire down.

The voices that most have moved the world have spoken first, out of the silences of heaven, a music that neither ear nor heart could resist. Such voices, if they be real and authentic, compel our judgment and convince our reason, and only the closed mind will sleep, only the prejudiced heart will resist.

The renascent heart, unconvinced by the *ipse dixit* of the misty ages, broods over the possibilities of some new system lying unborn in the womb of nature, whence all new life emerges; feels the quickening movement and hears the whispered promise of new birth to a fuller life, a larger conception, and a richer experience. For life is richer when our heavens grow larger, even though, meanwhile, the earth should dwindle.

Some will say that with the passing of myth, the poetry vanishes from the sky. But may there not be a new and nobler mythus in nature than the ancients ever dreamed. Let us make for ourselves a new expression of more beautiful poetry to celebrate the newly-ascertained fact. Be sure, that age is decadent which is looking to the past for its inspirations. Our age shall be young again in a new renaissance; then its poetry, inspired by new and loftier dreams, shall be sacred as that of David or Isaiah.

Amid those whirlwinds of change that swept across the gulf of time, Copernicus, though alive to the situation, kept his counsel and did his work faithfully and well. He had a residence within the precincts of the Cathedral and a country demesne besides. Two men and three horses were at his service. His associates in the chapter were men of education, taste and culture. One of these, Tiedemann Geise, afterwards became the bishop of Culm, and it was to him that Copernicus entrusted his manuscripts when at last he decided to have them printed.

From a species of terrace adjacent to the "Copernican tower" the eye wandered undisturbed across the blue expanse. In clear weather, one could discern afar, beyond the white dunes, the dark line of the Baltic Sea. The view on the east was interrupted only by the cathedral. It was here that Copernicus set up his "triquetrum," an instrument for taking the altitude of the stars. It consisted of three finely graduated parallel strips of deal, and was constructed by himself.

COPERNICUS AND "FREE SILVER."

Copernicus was at once bailiff, military governor, judge, tax collector, and vicar-general. Besides these stated duties, various commissions, and the practice of medicine on necessary occasions, he prepared for King Sigismund in 1532 a treatise on the currency.

The Polish Kingdom at this time included Thorn, Dantzic and a large part of Prussia. But a portion of Prussia, including Königsburg, had been erected by the Treaty of Cracow, concluded in 1525 between the king of Poland and Albert, Margraf of Brandenburg, into an hereditary fief for the benefit of the latter and his male descendants. As by this arrangement Margraf Albert held his feudal tenure subject to Sigismund King of Poland, the two countries were in a sense one. Copernicus set forth to his king what measures were necessary in order to restore stability to the much depreciated Prussian money, and maintain the value of the new coinage on a parity, so that it could circulate both in Poland and in Prussia.

After pointing out how useless it was to attempt to introduce into circulation, by the side of a depreciated currency, one of greater value, he explained how the introduction of a cheaper measure of value by the side of the higher one would drive the coin of greater value out of circulation.

"It is does not do to introduce a new and good money while the old is bad and continues to circulate, a much greater error is committed by introducing along side of an old currency a new currency of less value. This latter does not merely depreciate the old, it drives it away, so to speak, by main force."

Copernicus further observed that if the two countries were to be drawn together, and neither was to suffer the results which follow in the wake of a debased coinage, it was necessary for both to issue money of a similar degree of fineness. That fineness, he said, should be the full intrinsic value of the pure metal "with only so much alloy as may be necessary for the difference between the real value and the nominal value, to cover the cost of minting, which will avoid the principal attraction to remelt it."

He insisted that the value-ratio between gold and silver in the coinage should be precisely that of the gold bar to the silver bar. The whole contention of Copernicus reads wonderfully like a recent political speech such as a Republican orator might have delivered in a campaign in which a well-known candidate for the Presidency of the United States sought to readjust the ratio between gold and silver coinage in that country, using as a slogan, "They shall not crucify humanity upon a cross of gold." One may go back farther than Copernicus to find the currency problem. Aristophanes says in his "Frogs:"

> "Oftentimes have we reflected on a similar abuse
> In the choice of men for office and of coins for common use."
> (*Frere's translation.*)

This paper on the coinage was presented at the Diet of Graudenz. A single mint was to be established and a coinage of high standard was to be issued. The proposal was futile because it provided for the general welfare of two countries, whereas the members of the Diet cared only for their only personal interests. The question came up from year to year, and Copernicus pressed its importance upon the attention of the Diet, but the much needed reform did not prevail.

THE REFORMATION.

The Lutheran "reformation" was now becoming a powerful force in Prussia, and Martin Luther advised Margraf Albert to marry and exchange the spiritual dignity of grand master for the temporal one of duke of Prussia. The position of Copernicus became more and more difficult. Friends passed away. A new generation arose. A great evolution in life and thought shook all Germany. The doctrines of Luther had been received with only mild dissent, if not with distinct approval, throughout Ermland. Those who remained true to Rome hoped that by charity and patience the wanderers might be won back into united church. Of these latter was Copernicus. He appealed to that sweet reasonableness which lurked, as he suspected, in the souls of all thoughtful men.

The masses were swept into the great gulf of change, and passion acted in many cases before reason had time to speak. One of the Frauenburg chapter was accused of disloyalty, and Copernicus, of undue intimacy with the erring one. He submitted to the request that he would avoid such intimacy in the future, but with reluctance. The erring one was tried in Rome and acquitted, but the incident caused Copernicus much pain.

Beyond this incident, the eminent astronomer never had reason to feel that the church had been unfair. One of the bishops of Ermland had been very ungenerous, and, as far as he could, had made the life of Copernicus miserable for years, but this was merely a personal matter which the church as an institution never countenanced.

"DE REVOLUTIONIBUS ORBIUM COELESTIUM."

It remains only to tell the story of that important work which laid the foundations of astronomical science for all time, and gave to its author the most prominent place in its annals.

As already stated, the foundation of *De Revolutionibus* was laid at the castle of Heilsberg. This was in 1507-1509. When he went to Frauenburg, he began to make his more careful observations, the book was enlarged from time to time, and the last record was added in 1529, though it was not published till 1543. His work was interrupted by many duties. Twice he was obliged to reside at the castle of Allenstein while he administered the affairs of that district. These two visits covered about six years. For seven months he was acting as bishop of Ermland during an interregnum. He was appointed more than once to represent the interests of the chapter in their grievances against the King of Poland and the Teutonic knights. Still his occupations left him much time to pursue his astronomical work. He seems to have intended to disseminate the truth he had formulated as the Pythagoreans were wont to do, only by oral tradition. He had little care to be prominent himself and seemed to be utterly devoid of self-interest.

About 1530, a brief manuscript commentary was prepared by Copernicus for private circulation. Two copies of this MS. are still extant, one in Vienna, the other at Upsala. It closes with a *resumé* of his doctrines arranged in seven propositions. These are:

1. There is only one center to the motions of the heavenly bodies.
2. This is not the earth about which the moon moves, but
3. It is the sun.
4. The sphere of the fixed stars is indefinitely more distant than the planets.
5. The diurnal motion of the sun is a consequence of the earth's rotation.

[1] More, Colet and Erasmus.

6. The annual motion of the sun, and

7. The motions of the planets are primarily not due to their proper motion.

No secret was made of the new teaching, and Copernicus was not afraid of the church of which he was a faithful son. It is true as already stated that one of the bishops of Ermland was not friendly, but this was due to the knowledge that Copernicus, though he voted for his unfriendly rival, would have preferred another in that office.

It must not be supposed that Copernicus neglected the duties of his cathedral or of the church to devote his time to astronomy. As "visitator," as "nuncius capituli," as medical adviser to a trusted councillor of the Duke, who, by the way, was a heretic, he spent what time was necessary in these common or special duties, using only his leisure for more scientific pursuits.

From time to time, Copernicus was urged by his friends to publish his book. He had little fear of opposition so far as he himself was concerned, but he knew that the Lutherans were strongly opposed to it. Many scientists were also opposed, and he was much averse to stirring any controversy which might widen the breach between the two sections of a church already rent with disunion.

The friendships of George Joachim—or as he preferred to name himself, Rheticus—(1514-1576), provides a most inspiring story in the life of Copernicus. The incident opens in 1539, when the great astronomer was 66 years of age and Rheticus but 25. Years make some people think they are old. This is a great pity. Some of the most intimate and beautiful attachments subsist between persons of widely diverse ages. The friendship of Paul and Timothy was not more ideal than that of these two eminent mathematicians.

There is some doubt as to whether Copernicus would ever have consented to publish his work in full if Rheticus had not brought his eloquent appreciation to bear upon the master. It is true that Copernicus had made no secret of his views. Brief statements in script had been circulated privately, yet, although Cardinal Schönberg had formally demanded its publication, Copernicus still hesitated. His old friend Geise, now Bishop of Culm, had also used his persuasion, but it remained finally for his dear young friend Rheticus to prevail upon him to publish the complete work.

When Rheticus returned to Wittenburg after a visit which, though intended to be brief, had been prolonged for two years by the compelling influence of their growing friendship, he took with him the purely mathematical section of the work of Copernicus, and this was printed in 1541 under the title, "Trigonometry." It is almost certain that the master had given his young admirer reasonable assurance that the whole work would soon appear.

Accordingly, the book was sent to his old friend, the Bishop of Culm, with permission, if he wished, to have the work printed. The bishop sent it at once to Rheticus, who made arrangements to have it published in Nürnberg. No doubt this young scholar would gladly have seen the book through the press himself, but he had already been away from his chair in mathematics at Wittenberg for two years, and imagination can easily supply reasons why he should return to his university and—to his income.

Printing was still a new art. Nürnberg was hundreds of miles from Frauenburg, and even beyond Wittenberg nearly 200 miles. It was necessary to have some one look after it. Osiander of Nürnberg, a Lutheran scholar, astronomer, and minister, was interested, and he superintended the work. But unfortunately, the man had not the great soul that such a task demanded. A prefatory note, composed by Osiander, but unsigned, was inserted, setting forth that the work was merely the exposition of a theory and not in any sense intended as being final. This note went out as the word of Copernicus himself, and was removed only after centuries, and with much difficulty, by those who knew its falsity.

Osiander's note may have been inspired by the opposition of Luther and his followers. Luther himself characterized Copernicus as "a fool for holding such opinions . . . contrary to Scripture." Nevertheless Osiander's act was dishonest, and wholly misrepresented Copernicus' attitude. It remained in its false relation for over 300 years.

The offending note was as follows:

"Scholars will be surprised by the novelty of the hypothesis proposed in this book, which supposes the earth to be in motion about the sun, itself fixed. But if they will look closer, they will see that the author is in no wise to be blamed. The aim of astronomy is to observe the heavenly bodies and to discover the laws of their motions. The veritable cause of their motions, it is impossible to assign. It is consequently permissible to imagine causes, arbitrarily, under the sole condition that they should represent, geometrically, the state of the heavens, and it is not necessary that such hypotheses should be true or even probable. It is sufficient that they should furnish positions that agree with observations. If astronomy admits principles, it is not for the purpose of affirming truth, but to give a certain basis for calculation."

Besides the commitment of this falsity, Osiander added the last two words to the title of the book and made many changes in the text. There is some doubt as to whether the Congregation of the Index would have passed their famous decree of March 5, 1616, but for the discredit thrown on the Copernican system by Osiander's note.

In dedicating his book to Pope Paul III, Copernicus, no doubt, realized that he was helping the whole church to get a highly reasonable view of his work. This dedication is somewhat in the guise of an apologia. And yet one of its first sentences must have struck the reader as being strangely out of tune with the false note inserted by Osiander: "I am so much in love with my conclusions as not to weigh what others will think about them." He proceeds further: "The book had lain in my study, not nine years merely, but already going on four times nine." Then comes the spirit of the apolgia: "I knew that the liberty had been granted to others before me to postulate all sorts of little circles for explaining the phenomena of the stars. I thought I also might easily be permitted to try whether, by postulating some motion of the earth, more reliable conclusions could be reached regarding the revolutions of the heavenly bodies than those of my predecessors."

He now proceeds to tell of the plan of the work: "In the course of the book, I have followed this plan: I describe in the first book all the positions of the orbits together with the movements which I ascribe to the earth, in order that this book might contain, as it were, the general scheme of the universe," etc.

There are six books in the treatise, containing in all 130 chapters. The author shows that day and night are produced by the rotation of the earth and not by the revolution of the sun; that the seasons are the result of the inclination of the axis of the revolving earth as it passes through its orbit around the sun. He showed also the cause of the precession of the equinoxes in the varying inclination of the earth's axis.

The evidence of the earth's rotation as cited by Copernicus was very meagre. The evidence that the earth moves around the sun is found in the simplification of the phenomena by such an hypothesis. The stationary positions and backward loopings of the planets, which as actual facts seemed so fantastic, were shown to have no real existence. These were only apparent and depended upon the relative positions of the earth, the planets in question, and the stars.

Copernicus had still 34 circles in his system, yet he exclaims:

"Thus 34 circles suffice to make plain the entire structure of the world, the entire mazy round of the starry dance."—*Prowe Th.* ii. p. 292.

Forcaster employed 63 circles to explain the Ptolemaic system. But if Copernicus were right, then Mercury and Venus must have phases like our moon. "Have patience, time will tell," was the answer. Kepler (1571-1630) supplied the ellipse, Galileo (1564-1642), the telescope, and Newton (1642-1717) the law. Copernicus, Kepler, Galileo, Newton—these four, and lo, the new Astronomy.

It seems to be a law that the more sublime an idea is, the more opposition and ridicule it meets with. The doctrine of the earth's motion was made the subject of a farce and was put on the stage at Elbing during the carnival in 1531. Such frivolries still take place, little men still win immortality by opposing or misrepresenting great ones, and Elbing and Osiander have their counterparts in our own times.

That the Roman church placed Copernicus' book on the Index is not strange. The members of the Congregation of the Index saw Ptolemy opposed by Copernicus, Copernicus by Tycho Brahé, Tycho by Kepler, and all within their own memories. They were wrong only in their condemnation of a matter they in no wise understood. But in this too, history repeats itself. At Wittenberg, Rheticus and Reinhold were compelled to teach the Ptolemaic system just as Galileo, at Padua, had to confine his teaching to the exposition of Sacrobosco.

It is interesting to note that Francis Bacon rejected the Copernicus theory, while Milton accepted it. Tycho rejected, but Kepler accepted. Luther, Melancthon and Calvin rejected it with scorn. Pascal says: *"La silence éternel de ces espaces infinis me affraie."*

A destructive fate seems from the first to have attended the memoirs of Copernicus. We are reminded of the case of Horrox, many of whose writings and memoirs suffered a similar fate. Rheticus wrote a biography of Copernicus under his very eyes. It was therefore accurate. But it perished at birth, and was never printed. Other accounts of this life were written, but none were adequate till Dr. Leopold Prowe, after thirty years of careful research, published his *Nicolaus Copernicus* in 1883. A centenary edition of *De Revolutionibus Orbium Cœlestium* was issued at Thorn in 1873. This appears to have been the first copy printed without the Osiander note. A copy of this edition is to be found in the library of Toronto University. An excellent editorial in the *Edinburgh Review* is to be found in volume 158 of that periodical. It is based on Prowe's researches. Another valuable article, by E. S. Holden, LL.D., is printed in *Popular Science Monthly* for June 1904.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

Published by Scientific American Publishing Co.

New York, Saturday, September 27, 1919

Munn & Co., 233 Broadway, New York

Charles Allen Munn, President; Orson D Munn, Treasurer
Allan C. Hoffman, Secretary, all at 233 Broadway

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) 5.00
The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check.

Scientific American Publishing Co.
233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

Back Numbers of the Scientific American Supplement

SUPPLEMENTS bearing a date earlier than January 1st, 1918, can be supplied by the H. W. Wilson Company, 958-964 University Ave., Bronx, New York, N. Y. Please order such back numbers from the Wilson Company. Supplements for January 1st, 1918, and subsequent issues can be supplied at 10 cents each by SCIENTIFIC AMERICAN PUBLISHING CO., 233 Broadway, New York.

WE wish to call attention to the fact that we are in a position to render competent services in every branch of patent or trade-mark work. Our staff is composed of mechanical, electrical and chemical experts, thoroughly trained to prepare and prosecute all patent applications, irrespective of the complex nature of the subject matter involved, or of the specialized, technical, or scientific knowledge required therefor.

We also have associates throughout the world, who assist in the prosecution of patent and trade-mark applications filed in all countries foreign to the United States.

MUNN & CO.
Patent Solicitors

Washington Office: 625 F St., N.W. | 233 Broadway New York, N.Y. | Chicago Office: 801 Tower Bldg

Table of Contents

PAGE

Benzinoform in High-Tension Switches.—By M. Vogelsang . . . 194
Boring in Trinidad Asphalt Lake . . . 194
Diffraction of Electric Waves by the Earth . . . 192
Stress Lines in Steel After Permanent Deformation.—By A. McCance—Illustrated . . . 196
Electrical Phenomena in the Upper Atmosphere.—By S. Chapman—Illustrated . . . 198
Preparing Cork for Shipment—Illustrated . . . 200
Origin of Spectra . . . 200
Power from Tidal Waters . . . 201
Salinometer.—By H. S. Knowlton . . . 201
Constitution of the Earth's Interior . . . 201
Monistic and Dualistic Conceptions of the Stellar Universe.—By C. V. L. Charlier . . . 202
Prime Mover of High Efficiency—I.—By F. H. D. Acland—Illustrated . . . 204
Copernicus . . . 205

r 27, 191

reminded
ittings and
wrote a
s. It was
, and was
re written,
owe, after
s *Nicolaus*
De Revo-
Thorn in
by printed
is edition
rsity. As
is to be
is based
rticle, by
r Science

CAN

g Co.
19

Treasure-
y

year $5.00
. . 5.00
countries.
tion.
r check.

publish
distin-
nt arti-
ns, and
thought
orld.

ican

January
on Com-
rk, N. Y.
on Con-
d subse-
each by
roadway,

are in a
branch
omposed
ts, thor-
tent ap-
of the
echnical,

rld, who
mark ap-
United

Office:
er Bldg.

PAGE
sang 194
.... 195
.... 195
—By
.... 196
y S.
.... 198
.... 200
.... 200
.... 201
.... 201
.... 201
Uni-
.... 203
land
.... 204
.... 206